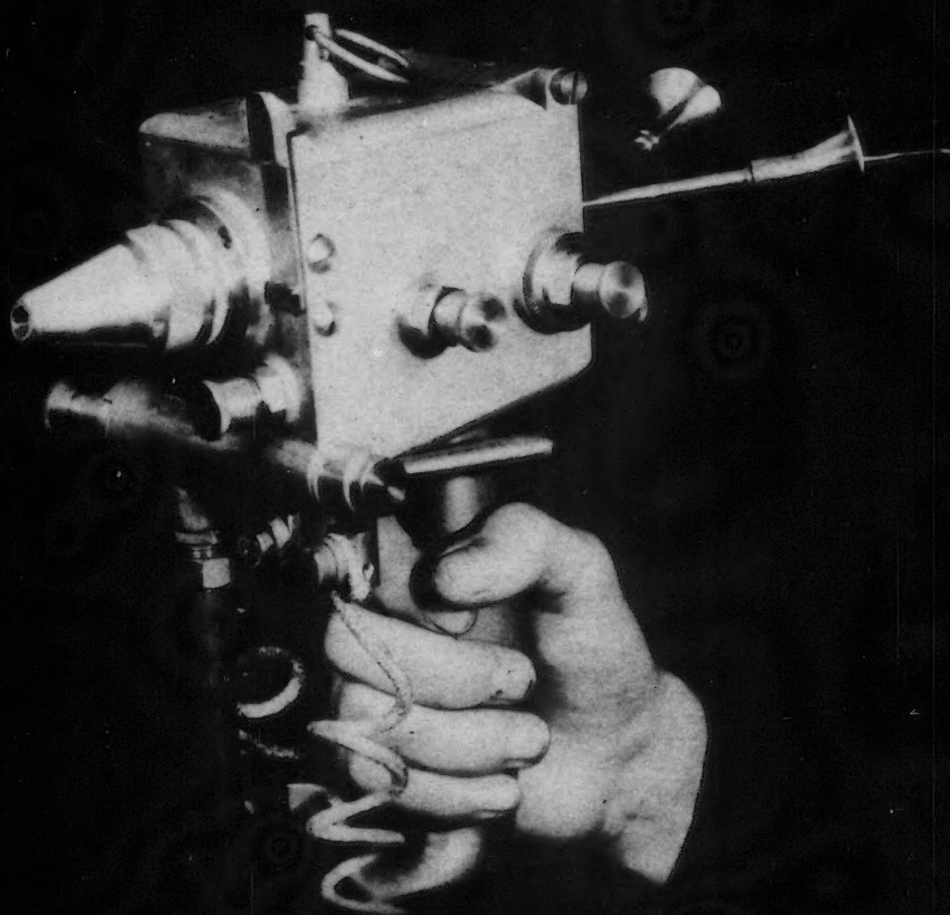


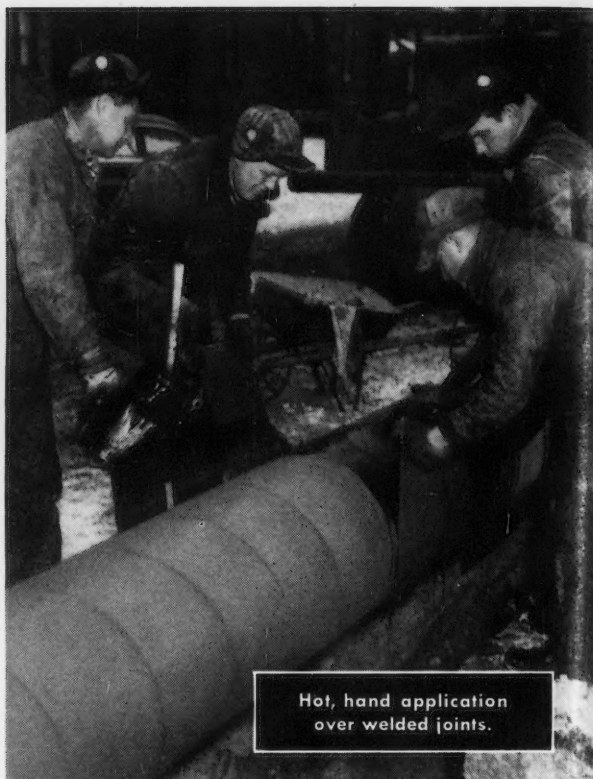
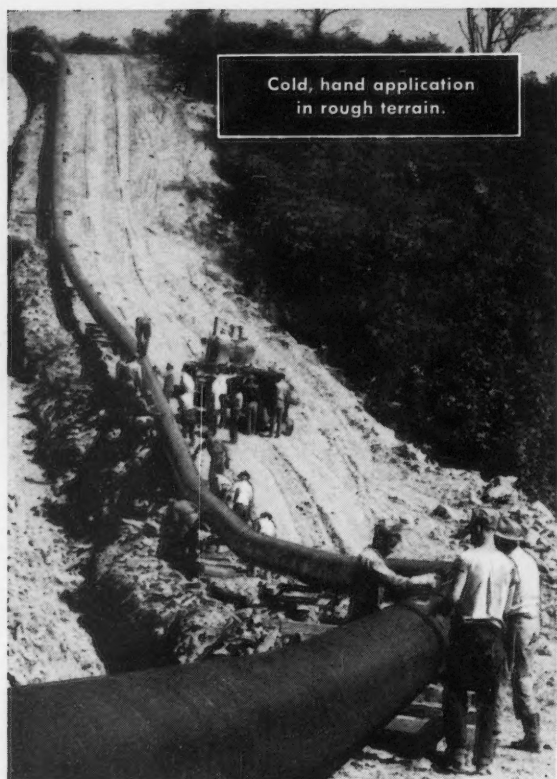
Corrosion

Official Publication of the
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



DECEMBER, 1951

No. 12



NO-OX-ID RUST PREVENTIVE MATERIALS add life time to pipe lines

For long-term, low-maintenance underground service, NO-OX-ID and NO-OX-IDized Wrappers can be applied by hand as shown above. This method is especially adapted to application over rough terrain, on short lines or congested areas and on field joints after welding.

COLD METHOD: A pliable, plastic, cold NO-OX-ID is rubbed on to $\frac{1}{32}$ " thickness.

NO-OX-IDized Wrapper is applied spirally as a shield, keeping the NO-OX-ID in intimate contact with the pipe—providing a tight seal against moisture and preventing abrasive damage. Then a final coating of NO-OX-ID is brushed on.

HOT METHOD: A length of NO-OX-IDized Wrapper is used as a granny rag to apply hot NO-OX-ID. The wrapper is then sealed to the coating around the pipe for permanent protection. Consult your Dearborn Engineer for the NO-OX-ID combination and method of application best suited to protect your next pipe job.

DEARBORN CHEMICAL COMPANY
Merchandise Mart Plaza • Chicago 54, Illinois

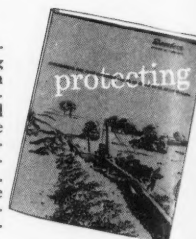
Dearborn
Reg. U. S. Pat. Off.

NO-OX-ID
IRON + = RUST

THE ORIGINAL RUST PREVENTIVE

GET THIS PIPE LINE BOOK

This informative illustrated book, "Protecting Underground Pipe from Corrosion With NO-OX-ID and NO-OX-IDized Wrappers," describes the hand application, traveling machine and stationary machine methods. Also contains coverage tables on each. The coupon is for your convenience.



Dearborn Chemical Company
Merchandise Mart Plaza, Dept. C
Chicago 54, Ill.

Please send my copy of "Protecting Underground Pipe from Corrosion With NO-OX-ID and NO-OX-IDized Wrappers."

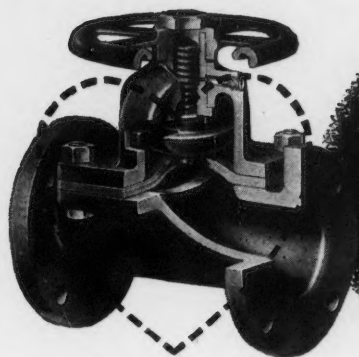
Name.....

Company.....

Address.....

City.....Zone....State.....

for the heart of the Saunders Patent Valve . . .



**Hills-McCanna offers
a complete selection of
diaphragm materials to best suit
your individual requirements**

Code Number	Base	Stock Type	Service Quality
R-1	Rubber	Carbon Black	Acid/Alkaline, Heat Resistant
R-2	Rubber	Non-Carbon Black	High Acid/Alkaline Resistant
R-3	Rubber	Carbon Black	Non-Fat Food Service
R-4	Rubber	Carbon Black	Special Non-Contaminating
R-5	Rubber	Non-Carbon Black	Acid/Alkaline, Abrasion Resistant
N-1	Neoprene	Carbon Black	Acid/Alkaline/Oil/Heat Resistant
N-2	Neoprene	Carbon Black	Fat Food Service, Non-Contaminating
N-3	Neoprene	White	Special Non-Contaminating
H-1	Hycar	Carbon Black	Acid/Oil/Heat Resistant
K-1	Butyl	Carbon Black	Acid/Heat Resistant
T-1	Tygon	Carbon Black	Acid Resistant
C-3	Compax	Carbon Black	Solvent Resistant
L-1	Special Polyethylene	White	Acid Resistant (66° Be Sulfuric)
M-1-25	Kel-F	Non-Carbon Black	High Acid/Alkaline Resistant

IN over 15 years of supplying Saunders Patent Diaphragm Valves to the processing industries, we have developed an extensive background of experience in the recommendation of the proper diaphragm material to meet a given set of conditions. This experience proves that only with diaphragms especially selected for your needs can you get the best service from your diaphragm valves. The wide range of diaphragm materials and their basic characteristics are shown in the table above. Each of these has advantages and limitations—no one is a cure-all—and the secret of successful selection of the right diaphragm is a thorough knowledge of these advantages and limitations.

Here at Hills-McCanna, recorded in the service records, is the experience that has resulted from valving over 2500 substances. This data is constantly being brought up to date to take into consideration the development of new diaphragm materials such as polyethylene and Kel-F. To any user of Hills-McCanna Valves, this record assures

you of having the knowledge gained from thousands of other installations working for you.

Whatever your valving requirements, if they involve handling corrosive substances, slurries, semi-solids or other hard-to-handle fluids, we would welcome the opportunity to go over your needs with you. Hills-McCanna Diaphragm Valves are available in sizes from 3/8" to 14" handwheel or lever operated or arranged for automatic or remote operation. Choice of 14 diaphragm materials, 48 body materials. Write for descriptive literature. HILLS-McCANN CO., 2460 N. Western Ave., Chicago 18, Illinois.

HILLS-McCANN
saunders patent
diaphragm valves

*Also manufacturers of Proportioning Pumps
Force Feed Lubricators • Magnesium Alloy Castings*

Shave

CORROSION COSTS

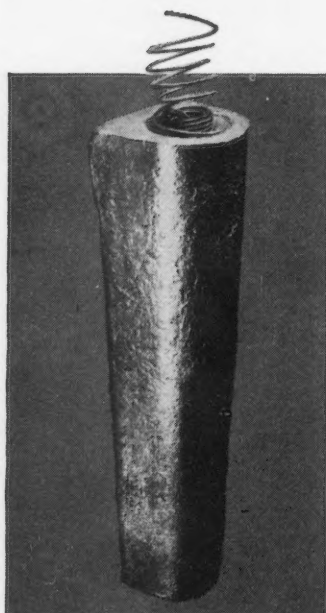


with

Long Life...High Efficiency

DOWELL

MAGNESIUM ANODES



Dowell magnesium anodes are alloyed to specifications designed for *maximum efficiency and long life*. The high degree of effectiveness was attained through years of intensive research and actual usage in many industrial applications.

Corrosion control with low-cost, expendable magnesium anodes was pioneered by The Dow Chemical Company over ten years ago. Today, Dowell, a subsidiary of Dow, offers you a complete line of

magnesium anodes to meet different industrial and marine applications—on pipelines, tanks and other underground and underwater metal structures.

With a nation-wide network of offices and complete research facilities, Dowell is well equipped to help you in planning an efficient cathodic protection system with Dowell magnesium anodes. For prompt advice, call the nearest office or write to Tulsa. Ask for literature on your corrosion problems.

DOWELL INCORPORATED • TULSA 3, OKLAHOMA
OFFICES IN PRINCIPAL CITIES

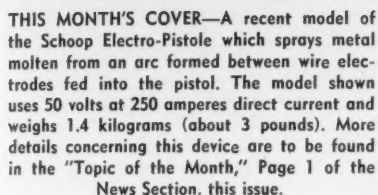
DOWELL

MAGNESIUM ANODES

GALVO-PAK® • GALVO-LINE

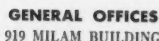
SUBSIDIARY OF THE DOW CHEMICAL COMPANY





EDITORIAL

A. B. CAMPBELL—(*Executive Secretary of NACE*)
Advertising Manager



803 Texas Avenue

Houston 2, Texas

Subscription: \$7.50 per year to non-members; Member's dues \$7.50, of which \$3.75 are applied as subscription to *CONSONANT*; Special rate, \$3.50 per year for public libraries and libraries of educational institutions. Additional copies to members 50 cents, to non-members, 75 cents. Foreign remittances should be by international postal or express money order or bank draft negotiable in the U. S. for an equivalent amount in U. S. funds. Entered as second class matter October 31, 1946, at the Post Office at Houston, Texas, under the act of March 3, 1879.

Corrosion is Indexed Regularly by Engineering Index.

devoted entirely to
CORROSION
research and control

Published monthly as its official journal, by the National Association of Corrosion Engineers, Inc., at Houston, Texas, U. S. A., to provide a permanent record of progress in the control of corrosion as described in papers prepared for the Association and from other sources.

Vol. 7

DECEMBER, 1951

No. 12



CONTENTS

	Page
Directory of NACE Regional and Section Officers	iv, v
Directory of Technical Practices Committees	xii
Officers and Directors, National Association of Corrosion Engineers	xvi

TECHNICAL SECTION

The Publications Committee	Page
By F. L. LaQue	409
Potential Measurements for Determining Cathodic Protection Requirements	
By Scott P. Ewing	410
Discussion: J. M. Pearson, R. B. Mears, L. F. Sudrabin, Page 417; W. J. Schwerdtfeger, Page 418.	
Sodium Hydroxide as Inhibitor of Pitting in 18-8 Stainless Steel	
By J. W. Matthews and H. H. Uhlig	419
Discussion: J. Pat Casey, Jr., Clifford B. Armstrong, Page 421; W. G. Renshaw, Page 422.	
Corrosion Aspects of Fusion Welded Aircraft High-Strength Aluminum Alloys	
By Loren W. Smith	423
Discussion: Hugh P. Goddard, Page 437.	
A Proposed Alternative Method for Measuring the Electrical Resistance of Pipe Line Coatings	
By J. K. Ballou, R. P. Howell, J. W. Liljeberg and P. F. Offermann	438
The Mechanism of Knife-Line Attack in Welded Type 347 Stainless Steel	
By M. L. Holzworth, F. H. Beck and M. G. Fontana	441
The Literature on Corrosion	
By Ivy M. Parker	450

DISCUSSIONS

Materials of Construction for Handling Sulfuric Acid 454
Kempton H. Roll

INDICES TO VOLUME 7, 1951

Title Page, Volume 7, Facing	Page 456
Index to Technical Material, Volume 7	
Index Headings from the Abstract Filing Index	
Tabular Index to Corrosion Technical Material	
Title Page, Corrosion Abstracts	
Tabular Index to Corrosion Abstracts	
Errata, Volumes 6 and 7	

NACE REGIONAL AND SECTIONAL NEWS

	Page		Page
Tache Section Files		Water Treatment Topic Discussed by	
Petition for Recognition	3	C. M. Brown	4
Huge Corrosion Loss Cited at Urbana	3	North Texas Section Hears Ellis D. Verink	4
Pittsburgh Arranges 8-Months' Schedule	3	E. D. Verink Addresses Houston Section	4
Fantana Will Speak at Philadelphia Meeting	3	Nov. 6	6
Five Months' Program For Chicago Given	3	San Francisco Bay Area Section Hears LaQue	6
Hydrogen Attack on Steel Topic at St. Louis	3	Hydrogen Attack on Steel Topic at St. Louis	6
Sabine-Neches Section Plans Six Meetings	4	Army Surface Corrosion To Be New York Topic	9

GENERAL NEWS OF CORROSION INTEREST

	Page		Page
Topic of the Month—Versatile Electric Arc	1	Secret Ballots on NACE Election Due Dec. 29	7
Metal Spraying Pistol Has High Potential	3	Sessions on Pipe Lines Held at API Meeting	8
Logan Accepts Post	4	Progress Made on 1952 Conference Program	9
Unclassified Technical Data May Be Exported	4	Indices to Corrosion Technical Material Printed	10
Corrosion Short Course Scheduled at UCLA	6	Book Reviews	14
Two Short Courses Set	6	NACE New Members	18
Twelve Papers Related to Corrosion at Metals Congress	7	New Products	22
Index to Corrosion Abstracts			25
Index to Advertisers			45

Copyright 1951 by the National Association of Corrosion Engineers. Reproduction of the contents, either as a whole or in part, is forbidden unless specific permission has been obtained from the Editor of CORROSION. Articles presented herein represent the opinions of their authors, and not necessarily those of the Editors of CORROSION. Officers and Members of the National Association of Corrosion Engineers. Manuscripts to be considered for publication should be forwarded, together with illustrations, to the Editor of CORROSION, 919 Milam Building, Houston 2, Texas.

Directory of NACE Regional and Sectional Officers

NORTH EAST REGION

- L. B. DONOVAN**, Director
Consolidated Edison Co.
of New York, Inc.
4 Irving Place
New York City.
- HUGH L. HAMILTON**, Chairman
The A. V. Smith Co.,
370 Trevor Lane
Bala-Cynwyd, Pa.
- T. P. MAY**, Vice-Chair.
The International Nickel
Co., Inc.
New York, N. Y.
- E. ROWLAND ENGLISH**,
Sec.-Treas.
Pipe Protection Service, Inc.
10 Center St.
Elizabeth, N. J.

Baltimore Section

- HOMER D. HOLLER**, Chair.
20 Hesketh St.
Chevy Chase, Md.
- GEORGE E. BEST**, Vice-Chair.
Mutual Chem. Co. of Am.
1348 Block St.
Baltimore, Md.
- L. G. VON LOSSBERG**, Sec.-Treas.
c/o Sheppard T. Powell
330 North Charles
Baltimore, Md.

Metropolitan Section (N.Y.)

- W. F. FAIR**, Chairman
Koppers Co.,
P. O. Box 390,
Westfield, N. J.
- KEMPTON H. ROLL**, Vice-Chair.
Lead Industries Assoc.,
420 Lexington Ave.,
New York, N. Y.
- F. J. LeFEBVRE**, Sec.-Treas.
Electro Rust-Proofing Corp.,
Box 178,
Newark, N. J.

Philadelphia Section

- H. F. McCONOMY**, Chair.
The Atlantic Refining Co.,
P. O. Box 8138,
Philadelphia 1, Pa.
- W. R. BRIGGS**, Vice-Chair.
W. A. Briggs Bitumen Co.
3303 Richmond St.,
Philadelphia 34, Pa.
- FRANK KAHN**, Sec.-Treas.
Philadelphia Electric Co.,
2301 Market St.,
Philadelphia 3, Pa.

Pittsburgh Section

- J. M. BIALOSKY**, Chairman
United States Steel Co.
210 Sample St.
Pittsburgh, Pa.
- N. P. PEIFER**, Vice-Chairman
Manufacturers L. & H. Co.
1801 Ellsworth Ave.
Carnegie, Pa.
- F. E. COSTANZO**, Secretary
Mfrs. Light & Heat Co.
2202 Vodeli St.
Pittsburgh, Pa.
- W. W. BINGER**, Treas.
Aluminum Res. Lab.
P. O. Box 772
New Kensington, Pa.



- 1—North East
2—North Central
3—South East
4—South Central
5—Western

Western New York Section

- GILBERT L. COX**, Chairman
International Nickel Co., Inc.
45 Exchange St.,
Rochester, N. Y.
- W. O. BINDER**, Vice-Chair.
Union Carbide & Carbon
Research Laboratories
Niagara Falls, N. Y.

- DR. JAY C. SEARER**, Sec.-Treas.
Durez Plastics & Chemicals,
Inc.
Walck Road
North Tonawanda, N. Y.

NORTH CENTRAL REGION

- FRANK L. WHITNEY, Jr.**, Dir.,
Monsanto Chemical Co.,
1700 S. Second St.,
St. Louis, Mo.

- EVERETT GOSNELL**, Chairman
Colonial Iron Works,
17643 St. Clair Ave.,
Cleveland, Ohio

- RUSSELL M. LAWALL**, Vice-Chair.
American Telephone & Tel. Co.
1538 Union Commerce Bldg.,
Cleveland 14, Ohio

- CARL E. HEIL**, Sec.-Treas.
Heil Process Equip. Corp.
12901 Elmwood Ave.
Lakewood 7, Ohio

Chicago Section

- FRANKLIN M. WATKINS**, Chair.
Sinclair Research Lab.
400 East Sibley Blvd.
Harvey, Ill.
- C. A. VAN NATTA**, Vice-Chair.
Plastic Lining Corp.
900-02 South Wabash Ave.
Chicago, Ill.
- LAURIE E. NICHOLS**, Sec.
Pub. Serv. Co. of Ill.
615 Eastern Ave.
Bellwood, Ill.
- H. L. O'BRIEN**, Treas.
Graver Tank Mfg. Co.
4809 Tod Ave.
East Chicago, Ind.

Cleveland Section

- L. W. DAVIS**, Chair.
Aluminum Co. of Am.
2210 Harvard Ave.
Cleveland, Ohio
- C. N. DETRICK**, Vice-Chair.
Williams & Co., Inc.
3700 Perkins Ave.
Cleveland, Ohio
- W. E. BAKER**, Sec.-Treas.
Standard Oil Co. (Ohio)
606 Standard Bldg.
Cleveland 14, Ohio

Detroit Section

- JACK H. LaPRETE**, Chairman
Spray-Coat Engineers Inc.
775 So. Bayside St.
Detroit 25, Michigan
- LEON D. COOK, JR.**, Vice-Chair.
Wyandotte Chemicals Corp.
North Plant
Wyandotte, Michigan
- W. R. CAVANAGH**, Treas.
Parker Rust Proof Corp.
2177 E. Milwaukee St.
Detroit 11, Michigan
- PROCTOR G. COATES**, Sec.
Michigan Bell Telephone Co.
618 Boulevard Bldg.,
7310 Woodward St.
Detroit 2, Michigan

Eastern Wisconsin Section

- HAROLD F. HAASE**, Chair.
2917 W. Juneau Ave.
Milwaukee, Wis.
- I. S. LEVINSON**, Sec.
Ampco Metal, Inc.
1745 South 38th St.
Milwaukee 46, Wis.

Greater St. Louis Section

- GEORGE A. FISHER, JR.**, Chair.
The International Nickel Co.,
Inc.
411 North 7th St.
St. Louis, Mo.
- W. F. GROSS**, Vice-Chair.
Tret-O-Lite Company
937 Pacific Ave.
St. Louis, Mo.
- WAYNE H. KELLER**, Sec.
Mallinckrodt Chemical Works,
65 Destrehan St.
St. Louis, Mo.
- GEORGE E. PURDY**, Treas.
7321 Zephyr Place
St. Louis, Mo.

Southwestern Ohio Section

- JOSEPH A. CREEVY**, Chairman
Newport Steel Corp.
Newport, Ky.
- ROY O. McDUFFIE**, Vice-Chair.
Dept. Chem. & Met. Eng.,
University of Cin.
Cincinnati 21, Ohio
- LEWIS M. LEDERER**, Sec.-Treas.
Inner-Tank Lining Corp.
1097 Wade St.
Cincinnati, Ohio

SOUTH EAST REGION

- A. R. SWANSON**, Director
American Telephone and
Telegraph Co.,
Hurt Building
Atlanta, Ga.

- E. P. TAIT**, Chairman
Alloy Products
333 Candler Bldg.
Atlanta, Ga.

- R. A. DAVIS**, Vice-Chair.
Chicago Bridge & Iron Co.
1500 N. 50th St.
Birmingham, Ala.

- H. C. VAN NOUHUYS**, Sec.-Treas.
Southeastern Pipe Line Co.
718 Forsyth Bldg.
Atlanta 3, Ga.

SOUTH CENTRAL REGION

- T. F. KELLY**, Director
James E. Mavor Co.
514 M & M Bldg.
Houston 2, Texas

- M. C. FLEMING**, Vice-Chairman
Phillips Petroleum Co.
Bartlesville, Okla.

- H. E. WALDRIP**, Sec.-Treas.
Gulf Oil Corp.,
5311 Kirby Drive,
Houston, Texas

- JOHN G. CAMPBELL**, Assistant
Sec.-Treas.
P. O. Box 1913
Corpus Christi, Texas

Corpus Christi Section

- THOMAS S. MOFFATT, JR.**, Chair.
Columbia-Southern Chemical
Corp.
Lawrence Drive
Corpus Christi, Texas
- JOHN W. NEE**, Vice-Chair.
Briner Paint Mfg. Co., Inc.
3713 Agnes St.
Corpus Christi, Texas
- CHARLES F. WARD**, Sec.-Treas.
Magnolia Petroleum Co.
2600 N. Port Ave.
Corpus Christi, Texas

Houston Section

- PERRY P. SPAFFORD**, Chair.
Stanolind Oil and Gas Co.
Box 3092
Houston, Texas
- CHARLES G. GRIBBLE, JR.**,
Vice-Chair.
Metal Goods Corp.
Box 1452
Houston, Texas
- L. G. SHARPE**, Sec.-Treas.
Humble Pipe Line Co.
Humble Building
Houston, Texas

(Continued Next Page)

Directory of NACE Regional and Sectional Officers

SOUTH CENTRAL REGION

• New Orleans-Baton Rouge Section

HENRY W. ALLEN, Chair.
Catholic Protection Service
149 Metairie Lawn Drive
New Orleans, La.

A. F. BLUMER, Vice-Chair.

PHILIP B. WOGAN, Sec.
P. O. Box 126
Westwego, La.

DARREL F. GRIFFITH, Treas.
Tretolite Company
Box 1181
Houma, Louisiana

• North Texas Section

H. L. BILHARTZ, Chairman
Atlantic Refining Co.
Box 2819
Dallas, Texas

J. C. SPALDING, JR., Vice-Chair.
Sun Oil Company
Box 2880
Dallas, Texas

N. P. CHESNUTT, Sec.-Treas.
Southern Union Gas Co.
1104 Burt Bldg.
Dallas, Texas

• Permian Basin Section

E. B. RAY, Chairman
Republic Natural Gas Co.
P. O. Box 1644
Midland, Texas

E. A. McCLENDON, 1st Vice-Chair.
Phillips Petroleum Co.
P. O. Box 6666
Odessa, Texas

R. L. ELKINS, 2nd Vice-Chair.
Shell Oil Co.
Box 1509
Midland, Texas

C. O. BUNDRANT, Sec.-Treas.
The Western Co.
P. O. Box 310
Midland, Texas

• Sabine-Neches Section

WILLIAM B. COOK, Chairman
Gulf Oil Corporation
P. O. Box 701
Port Arthur, Texas

CHRISTOPHER A. MURRAY,
Vice-Chairman.
Pure Oil Company
P. O. Box 237
Nederland, Texas

CHARLES A. RIDENOUR, Sec.-Treas.
Magnolia Petroleum Company
Beaumont, Texas

• Shreveport Section

TOM L. HOLCOMBE, Chairman
Holcombe & Stearns, Inc.
P. O. Box 1306
Shreveport, La.

MARION J. OLIVE, Vice-Chair.
Arkansas Natural Companies
General Engineering Dept.
Shreveport, La.

JAMES M. SMITH, Treas.
Interstate Oil Pipe Line Co.
Box 1107
Shreveport 83, La.

WM. F. LEVERT, Sec.
United Gas Pipe Line Co.
P. O. Box 1407
Shreveport 92, La.

• Tulsa Section

L. A. HUGO, Chairman
Phillips Petroleum Co.,
Bartlesville, Okla.

J. N. HUNTER, JR., Vice-Chair.
Service Pipe Line Co.,
P. O. Box 1979
Tulsa, Okla.

T. D. WILLIAMSON, JR., Sec.-Treas.
T. D. Williamson, Inc.,
Box 4038
Tulsa, Okla.

• University of Houston Junior Section

WM. G. BOYD, JR., Chairman
3401 Austin
Houston, Texas

JOHN A. QUINN, Vice-Chair.
511 Drew St.
Houston, Texas

BOB ARMSTRONG, Sec.
415 West Main St.
Houston 6, Texas

JAMES L. RICHARDSON, Treas.
2222 Jean St.
Houston, Texas

WESTERN REGION

I. C. DIETZE, Director
Dept. of Water and Power,
City of Los Angeles,
141 South Martel Avenue,
Los Angeles, California

L. L. WHITENECK, Chair.
Long Beach Harbor Dept.
1333 El Embarcadero
Long Beach 7, Cal.

W. M. SCHILLING, Vice-Chair.
Southern Counties Gas Co.
4818 Beck Ave.
Bell, Cal.

W. E. KIRKENDALL, Sec.-Treas.
Department of Water & Power
410 Ducommun St.
Los Angeles, Cal.

• Los Angeles Section

HARRY E. DOUGLASS, Chair.
Stewart R. Browne Mfg. Co.,
Inc.
1065 Riverside Drive
Los Angeles, Cal.

K. T. VANGSNES, Vice-Chair.
The Vanode Co.,
117 E. Colorado Blvd.
Pasadena, Cal.

CARL W. SHUPP, Sec.-Treas.
Sou. California Gas Co.
810 S. Flower St.
Los Angeles, Cal.

• Salt Lake Section

HARRY R. BROUGH, Chairman
Mountain Fuel Supply Co.
36 South State St.,
Salt Lake City, Utah

GEORGE R. HILL, Vice-Chair.
3725 South 11th East St.,
Salt Lake City, Utah

JOHN W. COX, Sec.-Treas.
Pipe Line Division,
Utah Oil Refining Co.,
Utah Oil Building,
Salt Lake City, Utah

• San Francisco Bay Area Section

DAVID HENDRICKSON, Chair.
East Bay Mun. Utility Dist.,
512 Sixteenth St.,
Oakland, Cal.

GEORGE WORKS, Vice-Chair.
Engineering Division
Union Oil Co. Refinery
Oleum, Cal.

CHARLES E. HANEY, Sec.-Treas.
Electric Steel Foundry
249 First St.,
San Francisco, Cal.

Technical Material Scheduled for Publication

JANUARY

Corrosion by Some Organic Acids
And Related Compounds
By H. O. Teeple

The Mechanism of Scale Formation
On Iron at High Temperatures
By B. W. Dunnington, F. H. Beck
and M. G. Fontana

Some Aspects of Ship Bottom Corrosion
By Paul Ffield

TOPIC OF THE MONTH—
Aluminum Alloys for Handling
And Storage of Fuming Nitric Acid
By W. W. Binger

NOTICE TO AUTHORS OF TECHNICAL MATERIAL ON CORROSION

The Editorial Review Committee and the Editor of Corrosion welcome the submission of technical articles on corrosion regardless of their length or content.

Persons interested in submitting material for publication are invited to write for "Guide for Preparation and Presentation of Papers," which gives complete information on the requirements of the association.

STOP RUST WITH RUST-OLEUM

For protection of rustable metal . . . inside and outdoors . . . RUST-OLEUM offers an economical solution under a wide range of conditions—salt air, dampness, industrial fumes and general weathering.

RUST-OLEUM can be applied even over rusted surfaces—no sandblasting or chemical cleaning is usually required. It is particularly effective for use in difficult-to-get-at places—where it is impossible or excessively costly to sandblast or chemically clean the metal. It is not necessary to remove all the rust. Just use sharp scraper and

wire brush to remove rust scale and loose rust.

For more than 25 years RUST-OLEUM'S capacity to stop rust has been demonstrated convincingly in many types of industrial applications by nationally-known manufacturers and leading railroads.

RUST-OLEUM can be obtained promptly from Industrial Distributors' stocks in principal cities of the United States and Canada. See our complete catalog in *Sweet's*, which also lists your nearest source of supply. Or, write on your company's letterhead for full information.



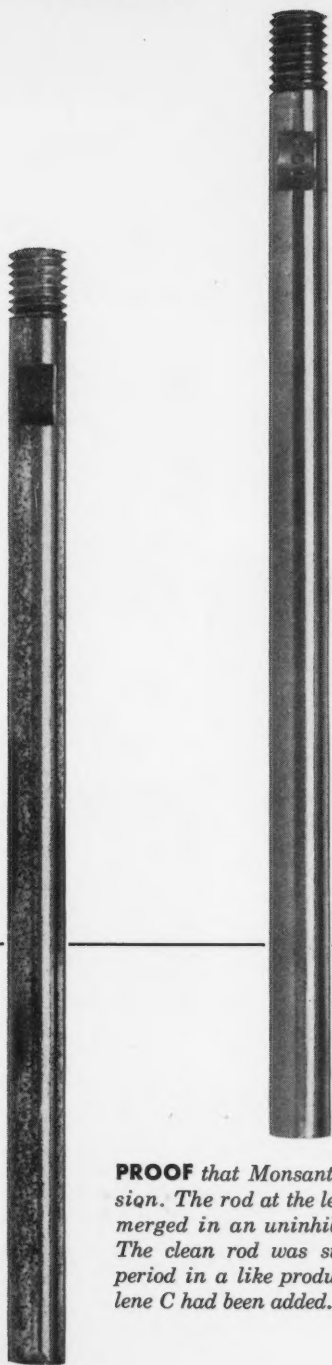
Available in many
COLORS
aluminum and white

**Beautifies as
it Protects**

"RIGID ECONOMY, MON!"

RUST-OLEUM CORPORATION
2436 Oakton Street, Evanston, Illinois

try SANTOLENE C to stop pipe-line corrosion



PROOF that Monsanto Santolene C stops corrosion. The rod at the left rusted while it was submerged in an uninhibited product for 12 weeks. The clean rod was submerged for an identical period in a like product to which 15 ppm Santolene C had been added.

The problem of internal corrosion of pipe lines carrying light petroleum products can be solved easily...with Monsanto Santolene C. Santolene C has the multifold advantage of protecting—with a single application—other transmission, storage and refinery facilities in addition to pipe lines. A small amount of Santolene C added to the product controls corrosion.

Santolene C has been proved effective in pipe-line service for more than a year. It is in use by independent and major oil refiners marketing all types of light petroleum products.

Since Santolene C is product-soluble, it burns completely with gasoline or diesel oil. It leaves no residue. Tests in both gasoline and diesel engines prove that Santolene C does not reduce engine cleanliness . . . does not cause injector or carburetor fouling . . . has no adverse effect on any factor of engine performance.

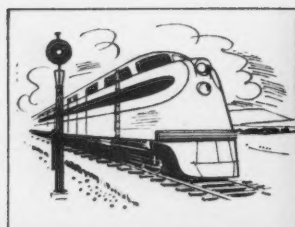
Try Monsanto Santolene C as the solution to your corrosion problem in light petroleum products . . . in refineries, lines, tanks, cars or ships. For technical information on the use of Santolene C, write, wire or telephone MONSANTO CHEMICAL COMPANY, Organic Chemicals Division, 1700 South Second Street, St. Louis 4, Missouri.

Santolene: Reg. U. S. Pat. Off.

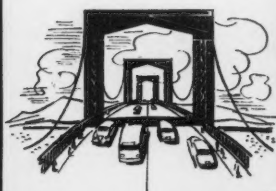


SERVING INDUSTRY...WHICH SERVES MANKIND

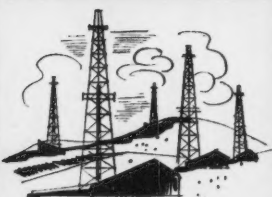
What's your Corrosion problem?



railway equipment?

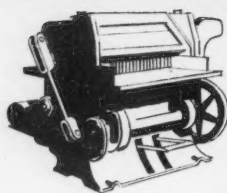
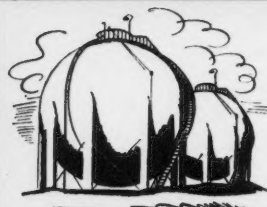


bridges?

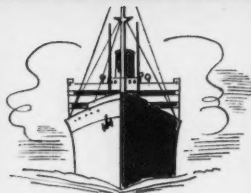


sour crude petroleum?

chemicals?



machinery?



ships?



pipelines?

Are you *stopping* corrosion . . . or are you merely throwing a weak "road block" in its way? Be sure to use the *right* corrosion-stopper—COROGARD coatings—for the particular corrosive conditions you must fight.

COROGARD protective coatings are sprayable, air-drying, highly impermeable coatings designed to meet varying corrosive conditions. Their base ingredients are vinyl resins, which have proved very effective in action.

Some COROGARD coatings are effective in inhibiting corrosion creep or undercutting. Others are highly impermeable to penetration of corrosive agents. Others have a tough, abrasion-resistant surface. Proper combinations of these component coatings provide durable systems to meet practically any service condition.

Get lasting protection from corrosion, and prolong the life of your metal *with a minimum of maintenance!* Use the *right* COROGARD coatings—available in a wide range of decorative colors—and end your corrosive problems. For more complete information on these money-saving, protective coatings, and for 3M's valuable COROGARD pamphlet, write 3M, Dept. 1512, 411 Piquette Avenue, Detroit 2, Michigan.

You'll find
the right
answer with

COROGARD
protective Coatings

COROGARD
PROTECTIVE
COATINGS

INVESTIGATE COROGARD SYSTEMS . . .

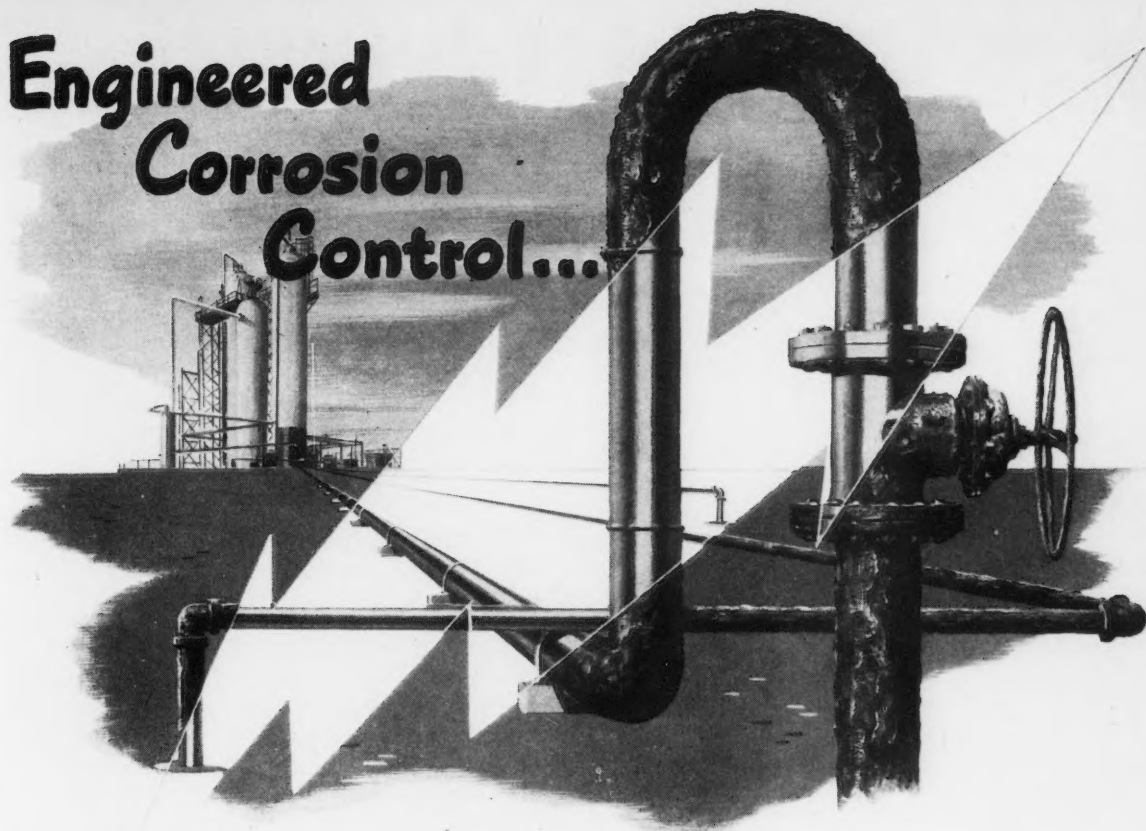
Moderate exposure • Severe exposure
Abrasion resistance • Skid-proofing • Sour
crude handling • Chemical fumes and spillage
• Maritime usages

MINNESOTA MINING AND MANUFACTURING COMPANY • ADHESIVES AND COATINGS DIVISION

GENERAL OFFICES: ST. PAUL 6, MINN.
EXPORT AND CANADIAN SALES: 270 PARK AVE., NEW YORK 17, N. Y.

411 PIQUETTE AVE., DETROIT 2, MICH.

Engineered Corrosion Control...



WITH *Harco* CATHODIC PROTECTIVE SYSTEM

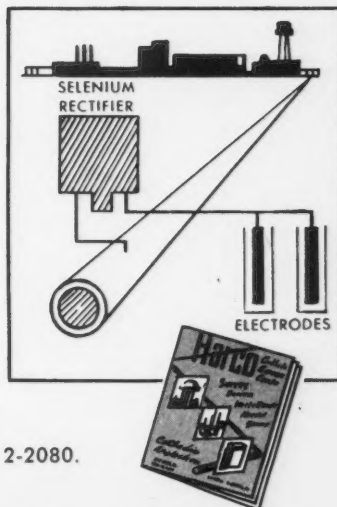
ENGINEERED TO YOUR CONDITIONS, HARCO SYSTEMS COMPLETELY ELIMINATE CORROSION in all types of pipeline installations, water storage tanks, metal conduit, etc.

HARCO ENGINEERING SERVICE includes the complete design and installation of cathodic protection systems to assure increased working life and reduce maintenance for installations normally affected by corrosion. In addition, these systems make possible lower depreciation rates and greater protection against personnel injury and property damage resulting from corrosion.

HARCO engineers consider every factor involved to guarantee complete cathodic protection in each individual installation. Among these variables are soil conductivity, moisture content, dissolved oxygen content, temperature, seasonal variations of environment, protective coatings, dissimilar metals, position of other metallic structures and presence of stray currents.

For complete and expert corrosion elimination service, specify HARCO. Write today for catalog or call MOntrorse 2-2080.

288 HC



THE

Harco

CORPORATION

*Cathodic
Protection
Division*

OFFICES IN PRINCIPAL CITIES

16691 Broadway • Cleveland, Ohio

BARRETT* COAL-TAR ENAMELS PROTECT AMERICA'S GREATEST PIPELINES

HERE ARE **10 REASONS** WHY...

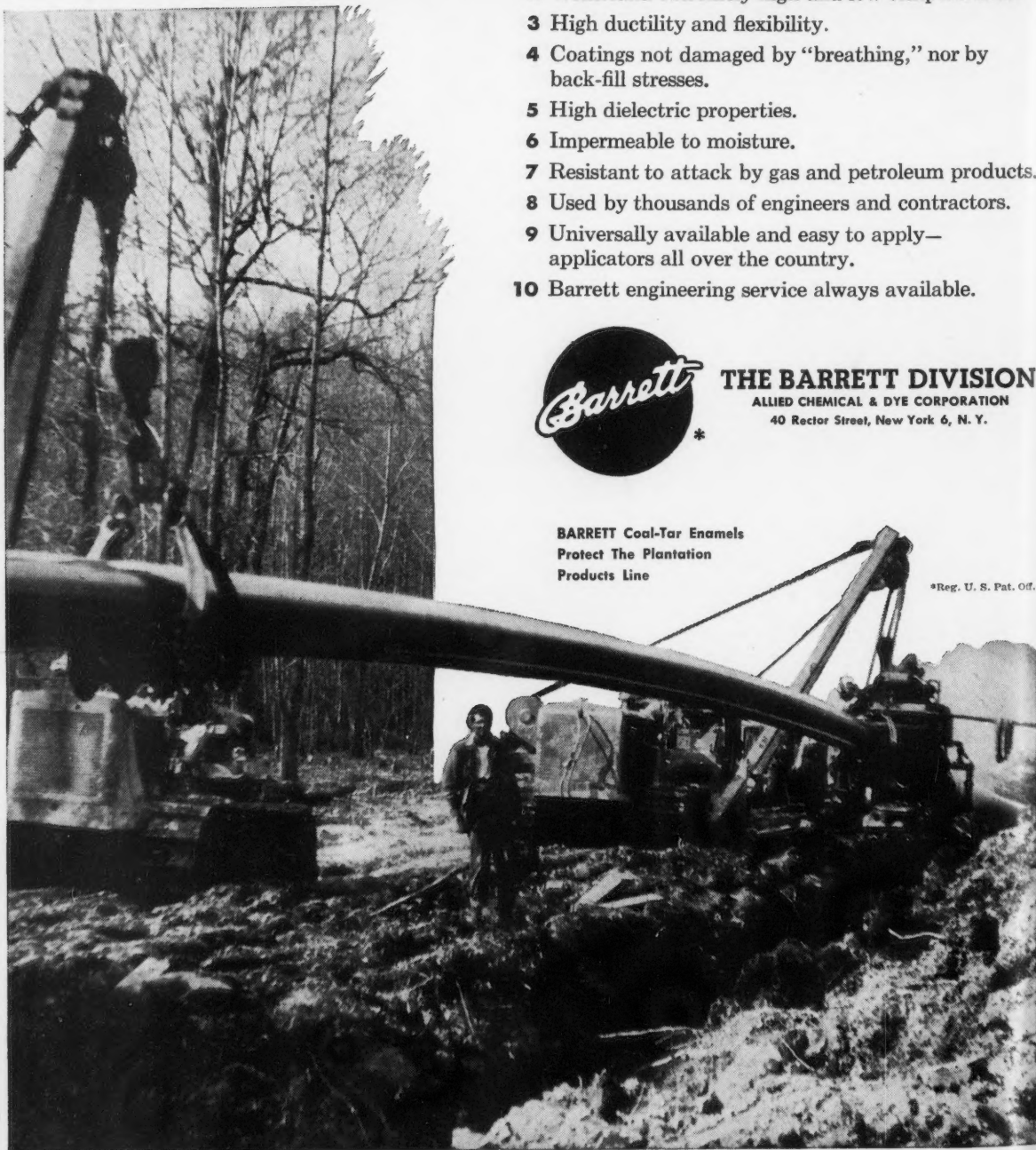
- 1 Products and procedures available for every oil and gas pipeline requirement.
- 2 Withstand extremely high and low temperatures.
- 3 High ductility and flexibility.
- 4 Coatings not damaged by "breathing," nor by back-fill stresses.
- 5 High dielectric properties.
- 6 Impermeable to moisture.
- 7 Resistant to attack by gas and petroleum products.
- 8 Used by thousands of engineers and contractors.
- 9 Universally available and easy to apply—applicators all over the country.
- 10 Barrett engineering service always available.



THE BARRETT DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.

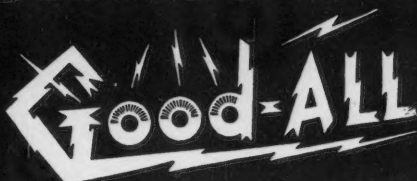
BARRETT Coal-Tar Enamels
Protect The Plantation
Products Line

*Reg. U. S. Pat. Off.

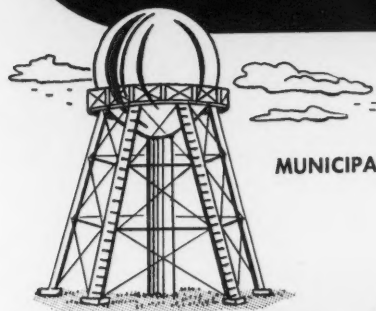


STOP CORROSION AND RUST

**NEW
DEPENDABLE**



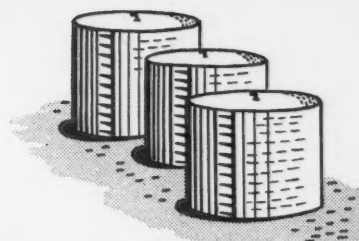
RECTIFIERS



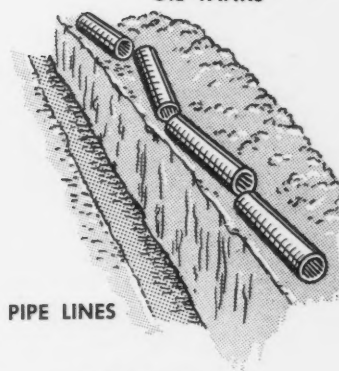
MUNICIPALITIES



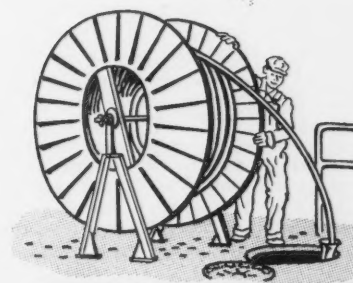
SELF COOLED - OIL IMMERSED



OIL TANKS



PIPE LINES



UNDERGROUND CABLES

PERFORMANCE PROVES IT . . . THEY'RE MORE DEPENDABLE

GOOD-ALL Rectifiers are among the most efficient in service today! The engineering "know how" and quality materials used in building GOOD-ALL Rectifiers is your assurance of dependable, trouble-free performance under the most severe conditions. And they are built to last—many units have been in operation over 13 years and are still in A-1 condition. You'll find GOOD-ALL Rectifiers the best Cathodic protection for all corrosion needs.

IN ADDITION TO OUR STANDARD MODELS

THE NEW "ADD-A-STACK RECTIFIERS"

Add One, Two, Three, Total of Four Stacks
Also models with Hermetically Sealed Stacks

GOOD-ALL ELECTRIC MFG. CO.

Ogallala , Nebraska

GOOD-ALL ELECTRIC MFG. CO.
Ogallala, Nebraska

Please send me Complete Information on Rectifiers Checked Below:

SELF COOLED
"ADD-A-STACK"

OIL IMMERSSED
HERMETIC SEALED

Name

Company

Address

City

State

DIRECTORY OF TECHNICAL PRACTICES COMMITTEES



TED S. ZAJAC, Chairman
Shell Oil Company,
50 West 50th St.,
New York, N. Y.

EX-OFFICIO MEMBERS

N. E. BERRY
MARS G. FONTANA
A. B. CAMPBELL

(Chairmen of all TP sub-committees listed below are members of the full committee)

TP-1 CORROSION OF OIL AND GAS WELL EQUIPMENT (Formerly Condensate Well Corrosion)

HARRY E. WALDRIP, Chairman
Gulf Oil Corp.
5311 Kirby Drive
Houston, Texas

H. L. BILHARTZ, Vice-Chairman
Atlantic Refining Co.
Box 2819
Dallas, Texas

TP-1A Pacific Coast. E. O. Kartinen, Chairman.
Signal Oil & Gas Co., 811 W. Seventh St.,
Los Angeles 55, Cal.

TP-1B Condensate Well Corrosion. R. C. Buchan,
Chairman. Humble Oil & Refining Co.,
Houston, Texas.

TP-1C Sweet Oil Well Corrosion. H. L. Bilhartz,
Chairman. Atlantic Refining Co., Dallas,
Texas.

TP-1D Sour Oil Well Corrosion. Co-chairmen: J. A.
Caldwell, Humble Oil & Ref. Co., Box 2180,
Houston, Texas, and R. L. Elkins, Shell Oil
Corp., Box 1509, Midland, Texas.

TP-1F Metallurgy—Oil and Gas Well Equipment.
Co-chairmen: V. V. Kendall, National Tube
Co., Box 266, Pittsburgh, Pa., and F. A.
Prange, Phillips Petroleum Co., Bartlesville,
Okla.

TP-1G Sulfide Stress Corrosion. R. S. Treseder, Shell
Development Co., Emeryville, Cal.

TP-2 GALVANIC ANODES FOR CATHODIC PROTECTION

WALTER P. NOSER, Chairman
Humble Pipe Line Co., Drawer 2220
Houston, Texas

TP-2A Correlation of Data From Operating Installa-
tions. L. R. Sheppard, Shell Pipe Line Corp.,
Houston, Texas.

TP-3 ANODES FOR USE WITH IMPRESSED CURRENTS

DONALD H. BOND, Chairman
The Texas Pipe Line Company
P. O. Box 2332, Houston 1, Texas

TP-4 MINIMUM CURRENT REQUIREMENTS FOR CATHODIC PROTECTION

J. M. PEARSON, Chairman
Sun Oil Co.
Bishop Hollow Road
Newton Square, Pa.

TP-5 CORROSION PROBLEMS INVOLVED IN PROCESSING AND HANDLING CHEMICALS

MARS G. FONTANA, Chairman
The Ohio State University
Columbus 10, Ohio

H. W. SCHMIDT, Vice-Chairman
Dow Chemical Co.
1313 Helen St.
Midland, Mich.

TP-5A Materials for Handling and Manufacturing
Sulfuric Acid. S. W. Shepard, Chairman,
American Cyanamid Co., Bound Brook, N. J.

TP-5B Design of Equipment for Corrosive Services.
W. W. Sweet, Materials of Engineering Div.,
Colgate-Palmolive-Peet Co., 105 Hudson Co.,
Jersey City 2, N. J.

TP-5C Subsurface Corrosion by Alkaline Solutions.
H. W. Schmidt, Chairman, The Dow Chemi-
cal Company, 1313 Helen Street, Midland,
Mich.

TP-5D Corrosion by Organic Acids and Bases. F. L.
Whitney, Monsanto Chemical Co., 1700 S.
Second St., St. Louis, Mo.

TP-5E Gasket Materials for Corrosion Service. L. D.
Cook, Chairman, Wyandotte Chemical Corp.,
Wyandotte, Mich.

TP-6 PROTECTIVE COATINGS

KENNETH TATOR, Chairman
Consulting Engineer, Montour St.
Extension, Coraopolis, Pa.

L. L. WHITENECK, Coordinator
West Coast Division
Board of Harbor Com.
Long Beach, Cal.

TP-6A Organic Coatings and Linings for Resistance
to Chemical Corrosion. Kenneth Tator, Chair-
man.

TP-6B Protective Coatings for Resistance to Atmos-
pheric Corrosion. G. G. Sward, Chairman.
National Paint, Varnish & Lacquer Ass'n,
1500 Rhode Island Ave., N.W., Washington,
D. C.

TP-6C Protective Coatings for Resistance to Marine
Corrosion. Raymond P. Devoluy, Chairman.
C. A. Woolsey Paint & Color Co., 229 E.
42nd St., New York 17, N. Y.

TP-6D Pipe Line Coatings. (Chairman not ap-
pointed).

TP-6E Protective Coatings in Petroleum Production.
Jack P. Barrett, Stanolind Oil and Gas
Company, Tulsa, Okla.

TP-6F Protective Coatings in the Food Industry.
G. W. Seagren, Chairman. The Mellon In-
stitute, Pittsburgh, Pa.

TP-6G Surface Preparation for Organic Coatings.
A. J. Liebman, Chairman, Dravo Corp.,
Dravo Building, Pittsburgh 22, Pa.

TP-6H Glass Linings and Vitreous Enamel. G. H.
McIntyre, Chairman. Ferro-Enamel Corp.,
Harvard & 56th St., Cleveland 5, Ohio.

TP-6I Metallic Coatings. (Chairman not appointed).

TP-6J Standards. G. G. Sward, Chairman.

TP-6K Corrosion Resistant Construction with Masonry
and Allied Materials. Robert R. Pierce, Chair-
man. Pennsylvania Salt Manufacturing Co.,
1000 Widener Bldg., Philadelphia, Pa.

TP-7 MATERIALS FOR USE AT HIGH TEMPERATURES

M. A. SCHEIL, Chairman
Director Metallurgical Research
A. O. Smith, Corporation
Milwaukee, Wisconsin

TP-8 CORROSION BY WATERS
V. V. KENDALL, Chairman
National Tube Company, Frick
Building, Pittsburgh 30, Pennsylvania

TP-9 CORROSION INHIBITORS
A. WACHTER, Chairman
Shell Development Company, 4560
Horton Street, Emeryville 8, California

TP-10 CORROSION FATIGUE
V. V. KENDALL, Chairman
National Tube Company, Frick
Building, Pittsburgh 30, Pennsylvania

TP-11 IDENTIFICATION OF CORROSION PRODUCTS

C. E. IMHOFF, Chairman
Research Supervisor, Chemical Lab.
Allis-Chalmers Mfg. Co.
Milwaukee 1, Wis.

TP-12 EFFECT OF ELECTRICAL GROUNDING ON CORROSION

GLEN APPLEMAN, Chairman
Pennsylvania Power & Light
Ninth & Hamilton St.
Allentown, Pa.

TP-13 ANNUAL LOSSES DUE TO CORROSION

TP-14 INSTRUMENTS FOR CORROSION MEASUREMENTS

TP-15 CORROSION CONTROL IN THE TRANSPORTATION INDUSTRIES

TP-16 ELECTROLYSIS AND CORROSION OF CABLE SHEATHS

IRWIN C. DIETZE, Chairman.
Dept. of Water & Power,
City of Los Angeles, Cal.

TP-16A Stray Railway Current Electrolysis. M. D.
Fletcher, Chairman, Illinois Bell Telephone
Co., 212 West Randolph St., Chicago 6, Ill.
J. Svetlik, Co-chairman, Northern Indiana
Public Service Co., 5265 Hohman Ave.,
Hammond, Ind.

TP-16B Corrosion of Lead and Other Metallic
Sheaths. B. B. Reinitz, Chairman, The
Okonite-Callender Cable Co., Inc., 730
Twenty-first St., Paterson, N. J. T. J. Mait-
land, Co-chairman, American Telephone &
Telegraph Co., 32 Sixth Ave., New York 13,
N. Y.

TP-16C Cathodic Protection of Cable Sheaths.
W. J. Schreiner, Chairman, Cincinnati Gas
& Electric Co., Cincinnati 2, Ohio. R. M.
Lawall, Co-chairman, American Telephone
& Telegraph Co., 1538 Union Commerce
Bldg., Cleveland 14, Ohio.

TP-16D Tests and Surveys. L. J. Gorman, Chairman,
Robin Beach Engineers Associated, 32 Court
St., Brooklyn 2, N. Y. Frank E. Kulman, Co-
Chairman, Consolidated Edison Co. of New
York, 4 Irving Place, New York 3, N. Y.

TP-16E Corrosion and Protection of Pipe-Type
Cables. Frank Kahn, Chairman, Philadelphia
Electric Co., 2301 Market St., Philadelphia
3, Pa.

TP-16F Nonmetallic Sheath Coatings. Geo. H. Hunt,
Chairman, Simplex Wire & Cable Co., 79
Sidney St., Cambridge 39, Mass.

TP-17 STANDARDIZATION OF PROCEDURES FOR MEASURING PIPE COATING CONDUCTANCE

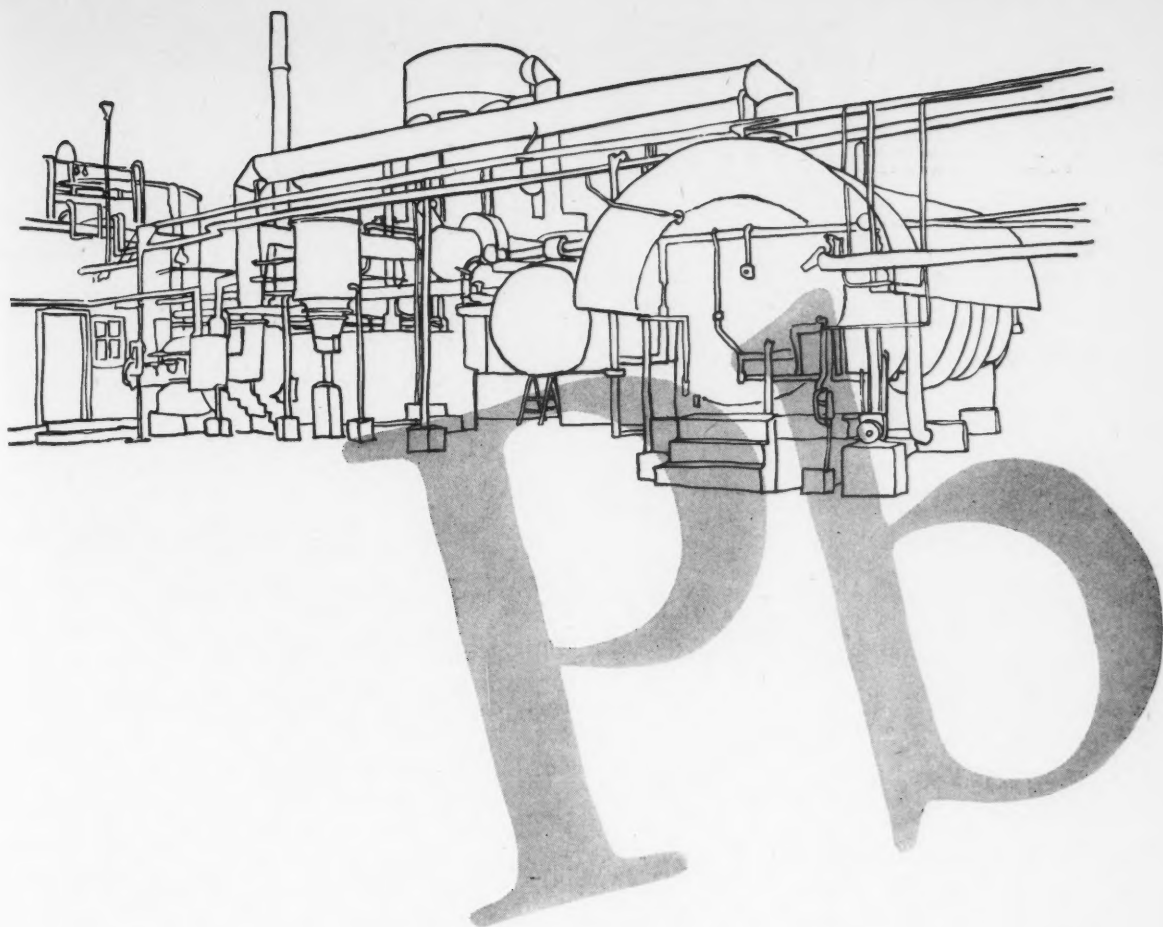
W. E. HUDDLESTON, Chairman
Huddleston Engineering Co.
Bartlesville, Okla.

TP-18 INTERNAL CORROSION OF FACILITIES FOR STORAGE AND TRANSPORTATION OF PETROLEUM

L. G. SHARPE, Chairman
Humble Pipe Line Co.
Houston, Texas

TP-19 CORROSION BY DE-ICING SALTS

F. E. KULMAN, Chairman
Consolidated Edison Company of
N. Y., Inc.
4 Irving Place
New York City



USING SULFURIC ACID?

Under many pressures, concentrations and temperatures, lead is the ideal material for handling sulfuric acid. It safely handles other corrosives as well.

For fabrication, lead is unique. Sheet lead can be welded, or "burned", to form a continuous lining; it can be bonded to another metal. Lead can be cast, die cast or pressure molded: extruded as pipe or other shapes; fastened by welding, flanging or bolting. Once installed, lead chemical equipment is easily repaired with a welding torch.

Because of the many complex factors in any corrosion problem, expert advice is usually advisable. For complete technical assistance, see Federated first. For lead products, think of ASARCO Brand lead pipe, lead sheet, and lead fittings.

Available in all standard sizes and forms through Federated's 22 sales offices across the country.

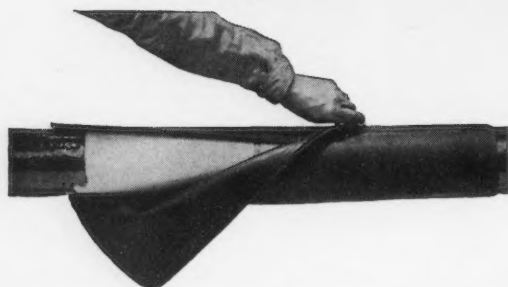
Federated Metals Division



AMERICAN SMELTING AND REFINING COMPANY • 120 BROADWAY, NEW YORK 5, N. Y.

DRESSER ZIPCOAT^{*}

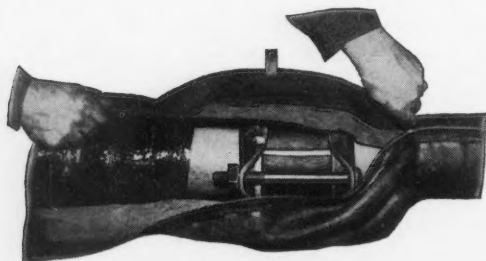
solve corrosion problem with a zipper...



ZIPCOAT is wrapped about the joint to be protected, and zipped tight. Every ZIPCOAT is complete with anaerobic microbiological corrosion inhibitor sealed in.



Ends of ZIPCOAT are folded back and cold sealing compound is applied to both ends. Ends are then straightened out and compound is applied over both ends and along zipper.



ZIPCOATs are also supplied for use on coupled joints. The application process is the same. The only difference is in the shape of the ZIPCOAT.

Workmen prefer ZIPCOATs to other types of field joint protection—no hot stuff or goop, no fumes.

Citizens Gas, Indianapolis, **USES 3500 ZIPCOATs TO SPEED CONSTRUCTION OF NEW 16" NATURAL GAS LINE**

ZIPCOATs were specified by Citizens Gas & Coke Utility Co. for good reason . . . they saved time and labor costs in protecting the 3500 field joints.

These zipper-fastened synthetic blankets are installed in 1/10th the time it takes to coat a joint, and they provide corrosion protection equaling or exceeding that of mill or yard-wrapped pipe.

It will pay you . . . just as it did Citizens . . . to know all the facts about ZIPCOATs before you tackle your next joint protection problem.

See your nearest Dresser sales engineer, or write today.

*ZIPCOAT is a trade-mark of Dresser Manufacturing Division

DRESSER MANUFACTURING DIVISION

Dresser Manufacturing Division, 59 Fisher Ave., Bradford, Pa. (One of the Dresser Industries). Warehouses: 1121 Rothwell St., Houston, Texas; 101 S. Bayshore Highway, South San Francisco, California. Sales Offices: New York, Philadelphia, Chicago, Houston, South San Francisco. In Canada: 629 Adelaide St., W., Toronto, Ont.

TYGON

Versus HCl

HYDROCHLORIC acid is as corrosive as it is versatile. Its destruction is as widespread as its application. However, through the correct use of the equally versatile family of TYGON plastic compounds, hydrochloric acid can be held in check—can be used without fear of costly corrosion.

Composed of skillfully modified polyvinyl resins, TYGON—as calendared or press polished sheet; as extruded tubing, solid cord, or channel; as molded goods; or, as a coating—represents the maximum possible in chemical resistance and physical properties. Naturally, the properties of TYGON vary according to the form in which it is used. But in every case, long experience and careful compounding assure the optimum. Proper application is the only needed step to completely satisfactory service with hydrochloric acid or other corrosive chemicals.

As a calendared or pressed polished sheet, TYGON is resistant to hydrochloric acid in any concentration up to 35% by weight and at temperatures as high as 165°-170° F. When subject only to the fumes of the acid, service temperatures can be raised to 200° F. Prolonged contact with mixtures of hydrochloric and other acids is not advised without the previous counsel of U.S. Stoneware engineers. In sheet form, TYGON is used primarily to line tanks, vats, drums, hoppers, bins, fume hoods and fume ducts. Substantial quantities are also cut into gaskets, washers, and diaphragms for use as long lasting, resilient seals or separators in pumps, valves, filters, piping, and a wide variety of process equipment.

As extruded tubing, cord, or channel, TYGON resists hydrochloric acid and its fumes in all industrial concentrations and at temperatures ranging up to 200° F. Lengthy exposure to mixed acids is not recommended without qualified advice.

In extruded form, TYGON has a wide range of application. Most important, however, is its use as flexible tubing and piping in both the plant and laboratory. Long lasting, flexible and transparent, TYGON Tubing is great improvement over glass and other tubing in many complicated lab "set-ups." In the larger sizes, up to 2" ID, the high strength, light weight, and smooth surface of TYGON Tubing qualifies it for use as flexible piping in permanent or temporary acid transfer lines, as gas lines, as syphon hoses, as flexible

connections, or as line desurgers. Where constant pressures of more than 40 psi are involved, particularly at elevated temperatures, braided jacket reinforcement is available and suggested.

Extruded cord and channel is generally used as gasketing, but also finds application as expansion jointing and as packing.

As molded goods, TYGON exhibits the same resistance to hydrochloric acid as its extruded form. Pressure and temperature limits vary according to size and design of the piece and the conditions of service, but usually are higher than those for the other forms.

Molded, TYGON takes the form of gaskets, grommets, washers, stoppers, closures, handles, bumpers, and special fittings. Where necessary, it can be reinforced with glass fibers for added strength.

As a coating, TYGON is available as a solvent type paint or as a plastisol. In either form, chemical resistance varies according to the thickness of the coat applied. Special consideration should be given to the limits of a thin film. In general, however, properly applied TYGON PAINT resists the fumes and spillage of hydrochloric acid in any concentration and at temperatures up to 200° F. The thicker coats of the plastisol (Tygoflex) are resistant at as high as 250° F.

As a paint, TYGON is used to protect all types of equipment, structural steel, walls, and ceilings. The number of coats to apply depends upon the conditions of service: a primer plus two topcoats is suggested for mild environments and a primer with no less than five top coats for severe exposures. TYGOFLEX finds use as a heavy duty coating and in the casting or "slush" molding of flexible parts and fittings. In coating work, it is applied by dipping or spraying on hot metal, and then fusing with heat.

TYGON, in any of its forms, is low cost insurance against the attack of not only hydrochloric acid and related chemicals, but a wide range of other acids, alkalies, oils, greases, and water. The different forms available and the range of mechanical, physical, and chemical properties they exhibit, permit the proper use of TYGON in many applications. Versatility and satisfaction in service is further assured by the custom engineering, compounding, and fabricating services available.



In addition to TYGON in its various forms, we also manufacture a number of other materials capable of handling hydrochloric acid in any concentration and under all types of operating conditions. These products include chemical stoneware and porcelain, acid proof brick and cements, homogenous lead linings, and other organic linings and coatings.

Why don't you submit your corrosion problem today? There's no obligation and we'll be pleased to be of assistance. So write, now!

253C

THE UNITED STATES STONWARE CO., Akron 9, Ohio

ENGINEERS, MANUFACTURERS, ERECTORS OF CORROSION-RESISTANT EQUIPMENT SINCE 1865

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

- (a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.
- (b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.
- (c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.
- (d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.
- (e) To promote standardization of terminology, techniques, equipment and design in corrosion control.
- (f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.
- (g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.
- (h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 919 Milam Building, 803 Texas Avenue, Houston 2, Texas.



Officers, 1951-52

<i>President</i>	N. E. BERRY Evansville, Indiana
<i>Vice-President</i>	M. G. FONTANA Columbus, Ohio
<i>Treasurer</i>	R. A. BRANNON Houston, Texas
<i>Executive Secretary</i>	A. B. CAMPBELL 919 Milam Building, Houston 2, Texas

Directors

President

N. E. BERRY.....1951-52
Servel, Inc., Evansville, Ind.

Vice-President

M. G. FONTANA.....1951-52
Ohio State University, Columbus, Ohio

Treasurer

R. A. BRANNON.....1951-52
Humble Pipe Line Company, Houston, Texas

Past President

VANCE N. JENKINS.....1951-52
Union Oil Co. of California, Wilmington, Cal.

Representing Active Membership

L. A. HUGO.....1951-54
Phillips Petroleum Co., Bartlesville, Okla.

S. D. DAY.....1950-53
S. D. Day Company, Houston, Texas

AARON WACHTER.....1950-53
Shell Development Co., Emeryville, Cal.

PAUL W. BACHMAN.....1949-52
Davison Chemical Corp., Baltimore, Md.

Representing Corporate Membership

H. A. HUMBLE.....1951-53
Dow Chemical Corp., Midland, Mich.

C. P. LARRABEE.....1951-53
United States Steel Co., Vandergrift, Pa.

V. V. MALCOM.....1950-53
The Philip Carey Mfg. Co., Cincinnati, Ohio

D. C. GLASS.....1949-52
Pure Oil Company, Chicago, Ill.

E. D. VERINK, JR.....1949-52
Aluminum Co. of America, New Kensington, Pa.

Representing Regional Divisions

L. B. DONOVAN.....(North East) 1951-54
Consolidated Edison Co. of N. Y., New York City

FRANK L. WHITNEY, JR.....(North Central) 1950-53
Monsanto Chemical Co., St. Louis, Mo.

A. R. SWANSON.....(South East) 1951-54
American Tel. & Tel. Co., Atlanta, Ga.

T. F. P. KELLY.....(South Central) 1950-53
James E. Mavor Co., Houston, Texas

IRWIN C. DIETZE.....(Western) 1952
Dept. of Water & Power, City of Los Angeles, Cal.

Directors Ex Officio

E. P. NOPPEL, Chairman Policy and Planning
Committee
Ebasco Services, Inc., New York, N. Y.

TED S. ZAJAC, Chairman Technical Practices
Committee
Shell Oil Corp., New York, N. Y.

F. L. LaQUE, Chairman Publication Committee
International Nickel Co., Inc., New York City

L. A. BALDWIN, Chairman Regional Management
Committee
Johns-Manville Sales Corp., New York, N. Y.

The Publication Committee

By F. L. LaQUE

Chairman, Publications Committee
National Association of Corrosion Engineers

THE FUNCTIONS of this committee are clearly indicated by its title.

The organizers of the National Association of Corrosion Engineers recognized the importance of publications by establishing the NACE journal *Corrosion*, as one of their first activities. This was a very bold step in view of the difficulties and risks in financing such a venture with the small funds that were available. Its recognized success has been due principally to four factors. The first was the untiring devotion of Ivy Parker who has been the Editor of *Corrosion*, from the start and, until this year, was also Chairman of the Publications Committee. The second was the financial support given by the first advertisers who had enough faith in the NACE and its journal to make their investment look to the future rather than to the immediate circulation. The third was the untiring efforts of the group who carried the ball in lining up the advertising in the early days. The fourth was the able efforts of our Executive Secretary and especially our Managing Editor Norman Hamner in getting out a magazine of which we can be proud and in seeing, with the help of the Advertising Committees, that we continue to secure enough advertising revenue so that *Corrosion* is a source of income rather than expense.

Two special sub-committees of the Publications Committee have contributed greatly to the present status of *Corrosion* and, because of it, to the stature of NACE as a whole. These are the Editorial Review Committee which has raised and is maintaining the standards of the many papers that are published.

The second is the Abstract Committee which has labored mightily and in minute detail to develop the abstract section so that it now represents the world's best guide to the current literature on corrosion and which has recently extended its value by publishing abstract cards designed for cross indexing and mechanical sorting. The Rules Committee has also made a worthwhile contribution in preparing the "Guide for Preparation and Presentation of Papers" which is very helpful to any author writing a paper for *Corrosion* or for presentation at an association meeting.

Corrosion magazine is by far the most important, but not the only publication of the NACE. The association has published books and committee reports which have found a prominent place in technical literature. In addition, through the facilities available in the Central Office there have been several other publication efforts, such as programs of meetings, letterheads for officers and committees and various announcements of sectional and regional activities.

Continued team work by the office staff and the committee will insure that our publications will always be a credit to the members of the association and will continue to warrant the support of our advertisers and subscribers who make these ventures possible.

Members of the Publications Committee, in addition to the chairman, are F. N. Alquist, P. W. Bachman, Marguerite Bebbington, Ivy M. Parker and E. R. Stauffacher.

Potential Measurements for Determining Cathodic Protection Requirements*

By SCOTT P. EWING

Introduction

THE MOST ECONOMICAL application of cathodic protection to buried or submerged structures requires a knowledge of minimum cathodic current requirements. There is a need for information on the relations, if they do exist, between current densities, potentials and corrosion of buried structures such as pipe lines. More specifically, the corrosion engineer should have at his disposal some means for determining, with a reasonable degree of precision, the cathodic currents required for providing adequate protection against corrosion. The sizeable expenditures now being made for the installation and maintenance of cathodic protection stress the need for making such applications in accordance with secure scientific and engineering principles. The importance of the problem of fixing minimum current requirements is further reflected by the action of the Technical Practices Committee of the NACE in appointing a committee to study the matter. After reviewing the replies to a widely circulated questionnaire, the committee chairman concluded that "no critical methods have been proved to determine the minimum current required for cathodic protection."

It is recalled that the Minimum Current Requirements Committee of the NACE recommended that three kinds of experiments should be developed; namely,

- 1) a constant current experiment; 2) a fixed electric field experiment utilizing small coupons; and
- 3) a constant polarization EMF experiment.

Since the work herein described was done in the fall of 1948, prior to the first meeting of the committee, the procedure employed was not exactly in accord with the committee's recommendations. The results are submitted with the hope that others will investigate similar and improved methods for determining minimum cathodic current requirements. It is felt that these results indicate that part of the original program proposed by the NACE committee may not be necessary.

General Discussion

The most widely used and generally accepted method for determining the current required for cathodic protection is based on the measurement of so-called "pipe-to-soil" potential. This measurement is usually made by obtaining a potentiometer reading



SCOTT P. EWING, employed by The Carter Oil Company, Tulsa, Oklahoma, since 1946 as corrosion engineer, was for ten years research associate on pipe coatings for American Gas Association and two years corrosion engineer, Panama Canal. He also spent four years on corrosion work with the Bureau of Ships, Navy Department. He holds a BS from Utah State Agricultural College, 1920, and a PhD in physics from University of California, 1925.

Abstract

An investigation has been made for the purpose of determining if buried or submerged steel pipe can be supplied adequate cathodic protection against corrosion by the maintenance of some constant open circuit potential. The experimental work consisted in establishing the open circuit potentials required to prevent corrosion of test pipe specimens exposed under a variety of conditions. Identical groups of six specimens each were exposed in four different environments. Test locations were selected to include as wide a variation in soil conditions as possible and one group of specimens was exposed in water.

Current was applied to five of the six specimens in each test group with the object of maintaining the open circuit potential of each specimen at a designated value. Measurements were made throughout the test of the open circuit potential and the amount of current supplied to each respective specimen. At the conclusion of the four tests, which were run for some 70-80 days, actual corrosion weight losses for all test specimens were determined and then correlated with the current and potential measurements. The results are presented and the data are explained and illustrated by accompanying graphs and tables. These data indicate that in each test environment there was a definite potential at which corrosion was stopped. This potential was found to vary with the environment, and in all cases, was less than -0.85 volt with reference to the copper-copper sulfate electrode. The test results also indicate that films, or coatings, formed by the applied current are of considerable importance in some soils in reducing current requirements, and that there is a definite advantage in applying sufficient current to form the coating as soon as possible after the cathodic protection installation is completed.

In appraising the test method used in this investigation the conclusion is reached that the method is apparently sound and that it can be used to determine what must be done to the pipe potential in order to prevent corrosion in any environment. The method appears to be capable of more precise results and recognition is made of the fact that further development and refinements are desirable. In this respect certain improvements are suggested for consideration.

* A paper presented at the Seventh Annual Conference and Exhibition, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951.

of the potential between the pipe and a copper-copper sulfate electrode, or other reference electrode, placed in contact with the soil over the pipe. The potential, as determined by this method on an unprotected pipe, may vary from about -0.3 to -0.7 volt. It has become the general practice to assume that the pipe is adequately protected when, upon application of protective current, the potential of the pipe is lowered to -0.85 volt with reference to the copper-copper sulfate electrode. Since the open circuit potentials of pipe lines and other structures vary over a wide range, depending on the exposure conditions, it seems unlikely that all lines would be protected when polarized to some arbitrarily set potential.

The limitations imposed by acceptance of a definite potential as a reliable criterion of cathodic protection become more apparent upon further examination. For instance, some unprotected structures undergoing corrosion attack have been observed to have already a potential more negative than -0.85 volt.¹ A brief and significant illustration of the reduction of the definite potential criterion to actual practice may be used for further clarification. Potential surveys along pipe lines usually show that in low, poorly drained areas the potential of the pipe is more negative than in the high, dry areas. The low areas are the anodic, and therefore, the corrosive areas. This is in accordance with the electrochemical theory; that is, the well-oxidized areas constitute the cathodic areas in the corrosion cell. The customary practice is to install anodes and rectifiers in the low, wet areas because leaks are, as a rule, most frequent at such locations. In other words, locations are selected where the potential is already the most negative and it is made still more negative. The axiom that corrosion is stopped when the cathodic areas are polarized to the open circuit potential of the anodic areas is thus ignored since actually no attempt is made to accomplish this.

As developed, it can be seen that the problem of providing adequate cathodic protection to buried structures entails not only 1) the most effective application of the required currents, but also 2) the selection of a precise method for determining when suitable protection is attained.

A solution to the second part of this problem, it is realized, can be attempted in different ways. For purposes of the investigation reported herein, it appeared desirable to determine if corrosion of buried or submerged steel pipe could be stopped by the application of a constant potential. Some discussion of the reasons for selecting this particular approach may be of benefit.

It is a well-established fact that in sea water the current required to prevent corrosion varies with time. A large current is needed initially, and as coatings are formed on the structure, current requirements become greatly reduced. This same effect is exhibited in some soils. The ampere hour requirement over a given time will be less if a large current is applied to the structure when the cathodic protection installation is first made. The difficulty of defining a definite minimum current requirement thus becomes apparent. It is desirable to maintain a uni-

form current density over an exposed surface subject to corrosion but this also constitutes a formidable problem in itself. In general, it is impossible to maintain uniform current density on engineering structures. On most types of specimens convenient for experimental use, the current density may also be far from uniform. The test specimen and the test itself must be carefully designed, otherwise current-requirements tests may well be meaningless.

If corrosion is stopped when the cathodic areas are polarized to the open circuit potential of the anodic areas, it may be assumed that any pipe line or like structure can be protected when polarized to some constant potential. More explicitly, if at one time the metal is protected by a certain potential between it and the adjacent soil, it is probable that the metal will always be protected by this same potential. With this reasoning in mind, a test method and procedure were accordingly developed for use in a constant potential experiment. The purpose of the experiment which was undertaken may be defined simply as an attempt to find how current density and corrosion varied on specimens maintained at constant potentials.

Description of Test

A. Preparation of Test Specimens

Test specimens were fabricated from new, 2-inch steel pipe. Each specimen when assembled consisted of two nipples 10 inches in length, a coupling, and two end caps of 2-inch size, all screwed together to form a single unit. The end caps were covered with an insulating coating, leaving an exposed external area of 1.20 square feet per specimen. The nipples and couplings, which constituted the exposed areas, were cleaned with acetone and were wire-brushed to remove loosely-adherent mill scale prior to assembly. They were stenciled for identification and weighed to 0.01 gram. An insulated copper wire was brazed to one cap of each test specimen. During assembly, the threads were coated with heavy grease and about one gram of potassium chromate powder was placed inside each specimen to prevent corrosion in the event water leaked past the threads. The 24 specimens so prepared were divided into four groups of six specimens each for test.

B. Test Sites

The four locations selected for purposes of the test are designated as Sites A, B, C and D. The soil at Site A, Tulsa, Oklahoma, was a light brown, fine sandy loam, or loam, which was compact and dry. It is shown on the Soil Survey map of Tulsa County as Bates very fine sandy loam. Since this location was near a producing gas well, salt water had probably contaminated the soil.

Sites B, C, and D were located at the Glenn Pool (Oklahoma) Station of the Interstate Oil Pipe Line Company. Site B was the water storage pond at the station. An analysis of the water is shown in Table I.

The soil at Sites C and D, near the pumping station, is shown as Miller loam on the Soil Survey

TABLE I
Analysis of Storage Pond Water at Glenn Pool Station

SiO ₂	12.0 ppm
Al ₂ O ₃ and Fe ₂ O ₃	2.4 ppm
Na ⁺	11.7 ppm
Mg ⁺⁺	19.0 ppm
Ca ⁺⁺	109.0 ppm
Cl ⁻	51.6 ppm
SO ₄ ⁻	47.7 ppm
HCO ₃ ⁻	309.0 ppm
Total	562.0 ppm
pH of water: 8.4	

map of Tulsa County. The soil at these locations appears to be typical of this particular soil except that the surface is a clay loam and is not calcareous until a depth of 10 inches is reached. At the time the specimens were exposed, the soil was rather dry to a depth of 24 inches and consisted of large, hard clods. The moisture content increased with depth, and at 48 inches, the soil was quite moist.

Results of resistivity measurements made at Site D, using the 4-terminal method with equal spacing of electrodes, are shown in Table II.

TABLE II Soil Resistivity Measurements at Test Site D	
Distance Between Adjacent Electrodes, Ft.	Apparent Resistivity, ohm cm
1	5000
2	3190
4	2110
8	1790

C. Electrical Circuits

The circuit arrangement employed in the test is shown schematically in Figure 1. The entire equipment was housed in a test box located at each test site. A 2-volt storage battery, which was replaced when necessary, supplied current to the potentiometer wire. The anode was placed in a symmetrical position with respect to the specimens. The coulometer used to determine ampere hours may be described as follows: It consists of a capillary tube with wire electrodes sealed in each end. The tube is filled with mercury, except for a few drops of a solution (225 grams of mercuric iodide and 750 grams of potassium iodide dissolved in a liter of water).^{2,3,4} The solution makes a break 3-4 mm long in the mercury column, and when current flows through the device, it removes mercury from the anodic side of the solution and plates it out on the cathodic side. Thus the drop of solution gradually moves toward the positive electrode. The maximum size of the capillary tube, which is limited by the stability of the

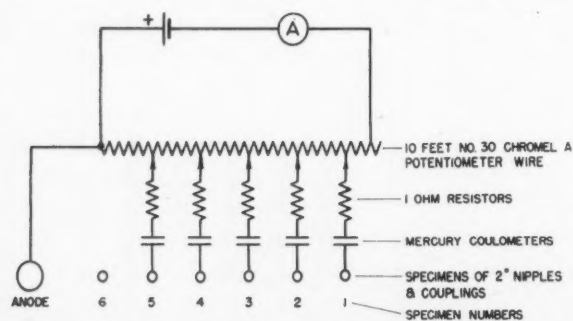


Figure 1—Schematic diagram of cathodic current requirements test.

mercury-solution interface, is about 3 sq. mm. The maximum permissible current is about 3 ma which causes a movement of the interfaces of about 6 mm per day.

Open circuit potential measurements were obtained by using a potentiometer and a saturated calomel electrode. The word "potential," as it is used, represents the potentiometer reading between the test specimen and the reference electrode placed far enough away from the specimen so that the reading is independent of the electrode position. There must be no net current flow to or from the specimen or other IR drops between the electrode and the specimen except those caused by galvanic currents on the specimen itself. The measurements of the true potentials of a group of cathodically protected pipe specimens is somewhat difficult but not impossible, as will be shown. Both theoretical considerations and measurements on a variety of structures indicate that the potential measured in the manner described is a true characteristic of the structure, and has a definite value at any time.

D. Test Procedure

The basic plan of the test was to determine the weight losses of test pipe specimens on which predetermined open-circuit potentials were maintained during exposure in different environments. Prepared specimens were exposed in the four different environments, Sites A, B, C and D previously described. Six specimens, numbered from 1 through 6, were exposed at each location. At Site A, the specimens were placed end to end in the soil at a depth of 12 inches. The specimens at Site B were suspended in a horizontal position 24 inches below the top of the storage pond cement wall. The water averaged about 12 inches in depth over the specimens, although the water varied in depth from a few inches to 24 inches during the test. Specimens at Sites C and D were buried in the soil at depths of 18 and 48 inches, respectively, in a manner identical to that used at Site A. In order to pack it around the specimens, the soil at Sites C and D was soaked with water to a depth of about one foot after it was placed in the trenches. Care was taken in filling the trenches to have the soil surrounding the specimens as uniform as possible.

Currents on the five samples were adjusted so as to keep the open circuit potentials, with reference to a saturated calomel electrode, as close as possible to the following values: -1.00 volt on No. 1; -0.90 on No. 2; -0.85 on No. 3; -0.80 on No. 4; and -0.70 on No. 5. No current was supplied to Specimen No. 6. By adjustment of the clips along the potentiometer wire, it was possible to control the current applied to each specimen and to determine the current by measuring the drop across the 1-ohm resistors.

The coulometers which were placed in series with some of the specimens measured the ampere hours, so that a continuous record of the current was obtained during the early part of the test when conditions were unstable. It was found, after the test started, that currents considerably larger than three milliamperes were required on some specimens. The

coulometers could not be used with those particular specimens. They were used only at the beginning of the test on specimens which required small currents. As the test progressed and conditions became more stable, it was found that the circuits were more stable when the coulometers were removed. The currents were then determined by measurement of the drop across resistors placed in series with the specimens.

Open circuit potential measurements were made by placing the reference electrode in contact with the soil directly over the specimen. All results are expressed with reference to the calomel electrode. The following procedure was adopted to eliminate the error caused by IR drop. The current flow to each specimen was first measured without any disturbance of the test arrangement. The leads to all specimens in the group were then opened, except for the one whose potential was being measured, and the current to this specimen was set at its original value. With a little practice and a few trials, the potential of each specimen could be measured by opening the circuit and quickly adjusting the potentiometer. It was, of course, necessary to wait until the closed circuit potential again became steady before making a second trial open circuit reading. The error in measurement of the open circuit potential was considered to be less than 5 millivolts. All measurements were made at approximately weekly intervals during the test.

Upon conclusion of the test, which was permitted to run for some 70-80 days, the samples were removed from their respective environments for cleaning and re-weighing. Soil adhering to specimens was taken off with water and wire brush. Specimens exposed at Sites A and B were cleaned electrolytically in a lead-lined tank containing 5 percent sulfuric acid inhibited with 0.5 gram of quinoline ethiodide per liter. Since electrolytic cleaning appeared to produce excessive attack of the mill scale on specimens exposed at Site A, specimens from Sites C and D were cleaned by careful scraping and wire brushing under running water. The specimens were dried after cleaning and re-weighed. Weight losses, current, and potential measurements were then correlated.

Discussion of Test Results

The test results are shown graphically in Figures 2 through 5a in which the data for each group of specimens are expressed as follows:

- 1) the variation with time of potential and cumulative milliampere days for each specimen; and 2) the relation between applied current and weight loss.

The values given for the cumulative milliampere days were obtained either from the coulometer or milliammeter readings, or both, at the beginning and end of each interval between measurements. Weight losses and applied coulombs are both expressed as milligrams of ferrous iron per square decimeter.

The electrical measurements for Site A are shown in Figure 2, and the weight loss data are presented in the accompanying Figure 2A. It will be observed that the potentials of all specimens, except No. 1A, drifted toward more positive values for the first 40

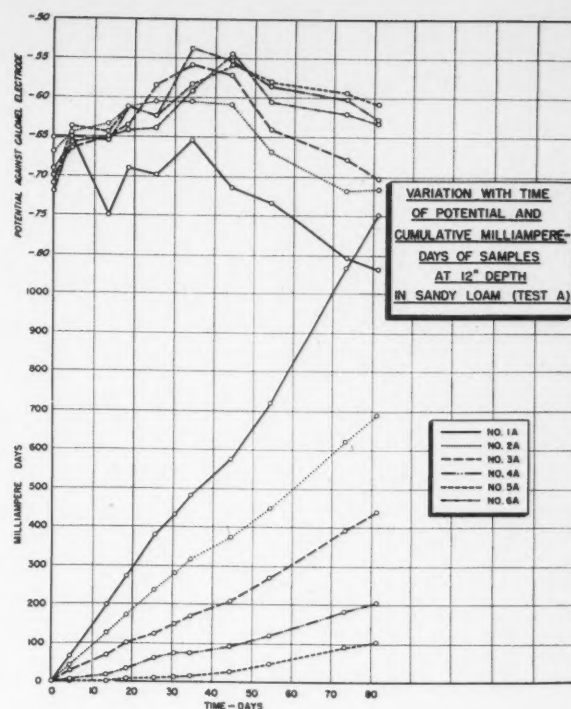


Figure 2

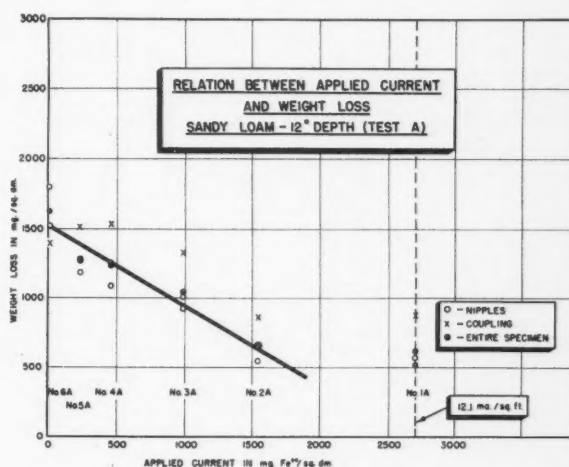


Figure 2A

days in spite of the fact that the current density on one of the samples was as great as 7 ma/sq. ft. The potentials were not held at the chosen potentials because such large current densities were not anticipated. It was thought at the time that perhaps most of the samples were adequately protected and it was decided to hold the currents at rather large steady values to see what would occur. Later the potentials did begin to shift to more negative values. This may be attributed directly to the fact that it did not rain until the 47th day at which time 0.60 inch rain fell. The total rainfall during the latter part of the test period was 2.35 inches.

All of the specimens from Site A showed considerable weight loss, as illustrated in Figure 2A. No

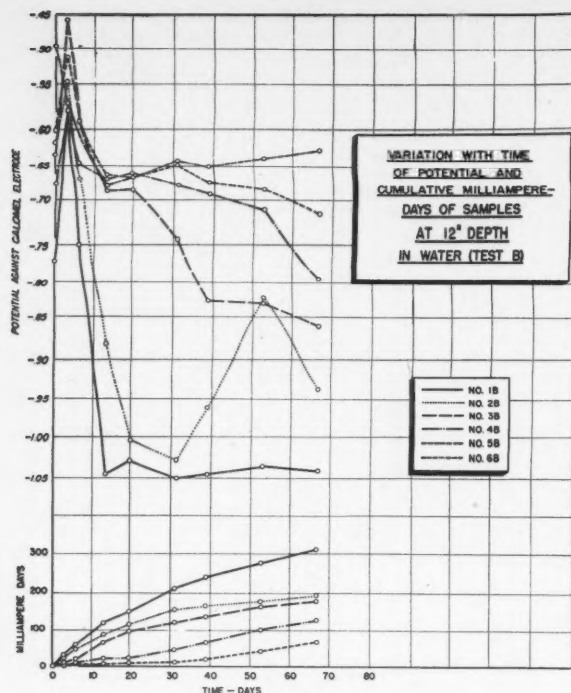


Figure 3

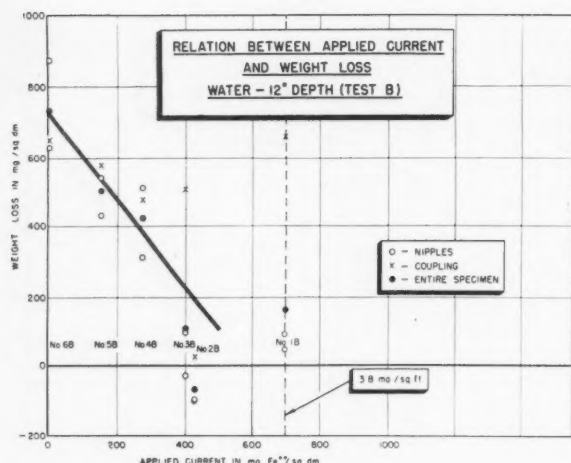


Figure 3A

noticeable corrosion products were present on Specimens 1A and 2A which had the highest applied current. Although the mill scale on either specimen was not appreciably attacked, there may have been some peculiar condition which caused it to loosen and come off at this location. The resulting loss in weight can hardly be considered as a true corrosion loss, and so it is believed that the weight losses for these two specimens should be considered as a cleaning loss. When this is assumed, it is seen that a current density of about 7 ma/sq ft is required for protection as indicated by Specimen 2A. This current density produced a polarization of 0.1 volt during the exposure period which changed the potential to about -0.71 volt with reference to the calomel electrode (-0.78 with reference to the copper-copper sulfate electrode). The average potential of Speci-

men 2A over the exposure period was -0.65 volt. Specimen 1A was obviously over-protected.

It will also be seen from Figure 2A that weight losses per unit area of the partially protected couplings were always higher than either of the nipples. This was usually the case for all the test sites. This is probably because the current densities were somewhat lower on the couplings, although the specimens were laid end to end in the trench, and as close together as possible. On an isolated cylinder, for example, the current density would be much higher on the ends. The effect was not caused by a galvanic potential between couplings and nipples because relative corrosion rates were frequently reversed in the specimens that received no current.

The method of plotting the weight loss data, as in Figure 2A, also provides a means for determining the effectiveness of the applied current. If corrosion conditions were uniform on all specimens, if there were no sources of error, and if cathodic protection were 100 percent effective (which is probably equivalent to saying that corrosion is cathodically controlled), then all the points would lie on a straight line with a slope of -1 . The slope of the line shown in Figure 2A is clearly less than -1 , even though the currents were held almost constant throughout the exposure period.

The data for the remaining test groups may be considered in somewhat less detail. It was possible to polarize the specimens at Site B quickly and with much smaller applied currents. This is shown in Figure 3. The applied currents were gradually adjusted so that the potentials reached their indicated values at about the end of the test period. These potential curves and those of Sites C and D show that the potentials were extremely unstable. This is typified by Specimens 1B, 2B, 4C, and 3D. If the current exceeded some particular value, the potential quickly dropped to about -1.00 volt, and if the current was slightly less than this value, the potential increased to about -0.80 volt. This instability is of interest because it is probably closely associated with the oxygen supply at the metal surface. If the current density is high enough to exhaust the oxygen, the surface becomes covered with hydrogen and acts as a hydrogen electrode. The converse is true if the current is lower than the rate of oxygen supply. Such instability in potentials would probably never be noted on a large pipe line where the current distribution would tend to adjust itself to the oxygen supply.

The weight loss data presented in Figure 3a indicate that Specimens 1B and 2B and the nipples of 3B were protected. As to the relation between potential and corrosion, Specimens 1B and 2B did not corrode and their potentials were below -0.90 volt most of the time. Specimen 3B was almost protected; its potential averaged about -0.70 volt but gradually dropped to -0.86 volt at the end of the test. A white carbonate coating was visible on 1B and no doubt it was formed on 2B and 3B because the milliampere hours applied to these samples were less than the corrosion rate of the unprotected specimen. By the same reasoning, coatings did not form on 4B, 5B,

and 6B. An analysis of the coating scraped from Specimen 1B, which had an average current density of 3.8 ma/sq ft applied during the test period, is given in Table III.

TABLE III

Analysis of Scale Removed From Pipe Specimen 1B

MgCO ₃	11.2%
CaCO ₃	80.2%
Ca(HCO ₃) ₂	1.1%
R ₂ O ₃	6.1%
Acid Insoluble	1.4%
Total	100.0%

The effect of oxygen supply on potentials and current requirements becomes evident when the results for Sites C and D are examined. The shallow (18 inches) C specimens did not require more current for protection but did require more current to produce the same potential change. Even though the currents were held reasonably steady, there were wide fluctuations in the potentials of those specimens which were to have been held near the central part of the potential range.

Considerable significance is attached to the weight loss data given in Figures 4a and 5a. Here is shown the effect of cathodically formed coatings in decreasing current requirements and the advantage of using sufficient current at the beginning. By way of illustration, a sufficient initial current stopped the corrosion of Specimen 4D so that the applied current was only 0.5 ma at the end of the test. On the other hand, Specimen 5D was about half-protected over the entire test period and was receiving about 1 ma at the conclusion of the test. The steep negative slope of the line in Figure 5a (greater than -1) can be explained only by the formation of a protective coating.

Current potential curves were run on different specimens at various times during the test.¹ The usual procedure was to measure the potential of the specimen quickly, with respect to the reference electrode, when the anode circuit was opened. These potential measurements were made for a series of increasing values of applied current. No particular difficulty was experienced in obtaining these curves and nearly all of them permit an estimate of the current required for protection at the time measurements were made. It should be stated that a single current-potential curve cannot be expected to determine the long term current requirement of a structure. For example, after the test had been in operation for several weeks, the current-potential curve on Specimen 1B gave a value of 0.5 ma/sq ft while the value was 3.3 ma/sq ft for Specimen 6B. Specimen 1B was over-protected and a coating had formed on it while Specimen 6B had received no protective current. It is quite possible in both cases that these specimens would have been protected by the same potential.

Interpretation of Test Results

The most significant findings of the test will be discussed first. The data obtained indicate that corrosion was stopped in each environment at a specific open circuit potential. These potential values varied about 0.1 volt between the different environments.

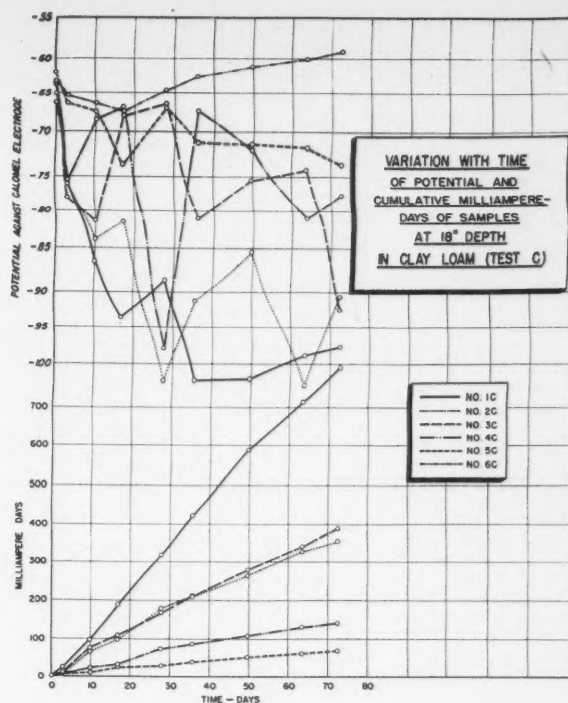


Figure 4

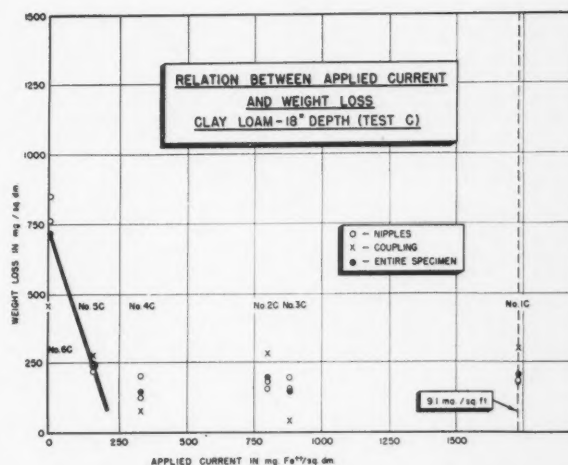


Figure 4A

They were 0.05 to 0.15 volt less (more cathodic) than the usually accepted value of -0.85 volt as measured with reference to the copper-copper sulfate electrode. It was not possible, as shown graphically in Figures 2 through 5, to keep the potentials near the originally set values by making current adjustments at approximately weekly intervals as was done. This was partly due to the fact that the potentials were inherently unstable. In this respect, larger current densities were required on some specimens than anticipated. In other cases, the instability was undoubtedly associated, as previously indicated, with the oxygen supply.

The relation between average potential, average applied current, and corrosion as shown by this test can perhaps be most easily explained and understood

TABLE IV
Summary of Data on Cathodic Current Requirements Test

Test Spec. No.	Adequate Protection Achieved	Average True Pot., V	Av. True Pot., Zero Current Specimen, V.	Increase Req. for Prot., V	Current Density Required*	
					From Test Data	From Cur. Vs. Pot. Curve
2A.....	Yes	-0.65	-0.63	0.02	6.9	6.2
3A.....	No	-0.64	-0.62	0.08	4.40	
3B.....	Yes	-0.70			2.22	0.5-3.3†
4B.....	No	-0.65			1.52	
5C.....	Yes	-0.69	-0.63	0.06	0.80	2.2†
6C.....	No	-0.63			0.00	
4D.....	Yes	-0.76	-0.69	0.07	0.80	1.65†
5D.....	No	-0.71			0.52	

Specimen Designations:

- A. Sandy Loam, 12-inch depth.
B. Water, 12-inch depth.
C. Clay loam, 18-inch depth.
D. Clay, 48-inch depth.

* Expressed as milliamperes per square foot.

† These values are for samples on which coatings did not form.

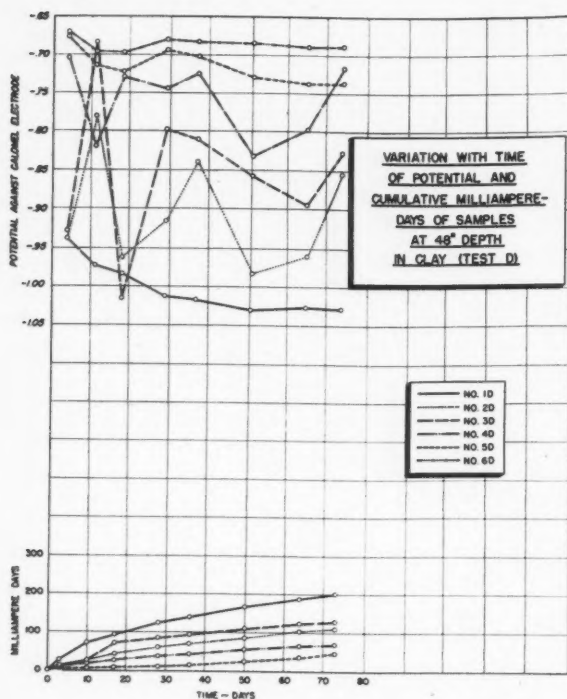


Figure 5

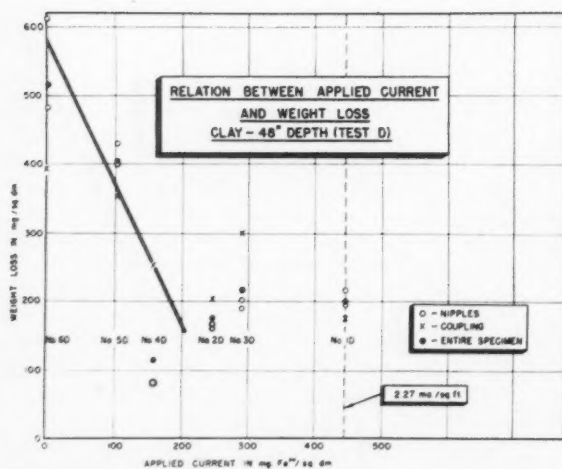


Figure 5A

by a presentation of the pertinent data as is done in Table IV. This table in effect summarizes the test results. These results indicate that the lowest average potential required to prevent corrosion was -0.76 volt which corresponds to -0.83 volt with reference to the copper-copper sulfate electrode. (The calomel electrode is about 70 millivolts negative to the copper-copper sulfate electrode, so all potential measurements can be converted to copper-copper sulfate potentials by the addition of 0.07 volt; that is, -0.76 volt (calomel)

= -0.83 volt (Cu-CuSO₄.) It appears that in dry, well aerated soils protection is obtained at a less negative potential. In the well-drained and rather dry soil, the protective potential was about -0.70 volt. It should be noted that in all cases protection was obtained with less than 0.1 volt polarization. Current density values shown in the table illustrate the fact that current-potential curves could not be used to determine long time current requirements.

The formation of coatings, or protective films, as indicated by the test data is advantageous. After they are formed current requirements are reduced, and as can be seen, their early formation is desirable.

With regard to the test method itself, the results indicate it to be sound in principle. Certain difficulties were encountered in its initial application. The potentials were not maintained with the degree of accuracy desired and for that reason it is desirable to design a circuit which would automatically hold the potentials at chosen values. The weight losses designated as cleaning losses may actually have been corrosion losses that occurred during the early part of the test. In order to prevent such an occurrence, the current source should be capable of supplying large currents when the test is started. If the cleaning errors can be minimized in this manner, and the weight losses are plotted as in the accompanying figures, it might be possible to determine the protective potential with an error no greater than approximately 0.03 volt. Other improvements which might be suggested involve improvement in cleaning methods and greater care in placement of the soil about specimens in order to establish equilibrium conditions in a shorter time.

Conclusions

The study that has been made to determine if adequate cathodic protection can be afforded pipe lines, or other buried structures, by maintenance of a definite potential on the structure has yielded data from which the following conclusions are drawn.

1. Pipe lines, or other buried or submerged structures, can be protected against corrosion by maintaining them at some definite potential with cathodically applied current.
2. The exact potential at which corrosion is stopped will vary with the environment. It follows that if the environment changes with seasons, rainfall, etc., the protective potential may also vary.
3. The potential required for protection is less negative than -0.85 volt with respect to the saturated

copper-copper sulfate electrode for typical pipe line environments.

4. The change in potential or the polarization necessary for protection of pipe lines is probably always less than 0.1 volt.
5. The current required to maintain a definite negative potential may be very large when current is first applied. If the current produces a coating on the metal surface, the current required will be greatly reduced.
6. There is evidence to indicate that protection over a given time is attained with the least energy expenditure when the structure is maintained at the required potential for protection.
7. The test method described in this report can be used to determine what must be done to the potential to stop corrosion in any environment. The method itself appears to be capable of much more precise results which will probably show that even less polarization and less negative potential will give complete protection.
8. Certain refinements in the method are needed. There would be little use in further experiments until an automatic current control is devised which will hold the true potentials reasonably constant. For this reason, it is hoped that the results thus far obtained with the constant potential method will induce others to conduct similar tests in other environments and with improved circuits.

Acknowledgments

The writer wishes to thank the management of The Carter Oil Company and the Standard Oil Development Company for permission to publish the paper. He also wishes to express his appreciation to Mr. A. C. Broyles for assistance in preparation of the paper and to Mr. A. W. McMurtrey for assistance in the experimental work.

References

1. Cathodic Protection of Casings in the Loudon Pool. S. P. Ewing and J. F. Bayhi. *Corrosion*, 4, No. 6, 264-286 (1948).
2. R. A. Lehfeldt, *Phil. Mag.*, 3, 158 (1902).
3. H. S. Hatfield, *Elektrochem*, 15, 728 (1909).
4. New Precision Coulometer. Abers & Newton. *J. Phys. and Colloid Chem.*, 52, No. 6, 955-958 (1948).

DISCUSSION

Question by J. M. Pearson, Sun Oil Co., Newton Square, Pa.:

Was a bridge circuit used for measuring potential?

Question by R. B. Mears, United States Steel Co., Pittsburgh, Pa.:

Do you find that interruption of the current prior to measuring the polarized potential of the test specimen affects the measurements obtained?

Comment by L. F. Sudrabin, Electro-Rust-Proofing Corp., Newark, N. J.:

Dr. Ewing's observation that effective corrosion control by cathodic protection can sometimes be obtained at potentials other than -0.78v measured against a sat. KCl calomel half cell is also suggested by a preliminary study conducted as a part of the Minimum Current Requirements for Cathodic Protection T. P.-4 Program.

In the test, five of six hot rolled steel panels are maintained at fixed potentials of -0.60v , -0.65v , -0.70v , -0.75v and -0.80v respectively measured against a sat. KCl calomel half cell. The sixth panel is used as the control. Weight losses determined at the end of the 14-day test are used to determine the corrosion activity on each panel.

Test Conditions

Cell—Each panel is placed in a separate lucite cell 8-inch x 8-inch x 4-inch.

Water—Belleville, N. J., tap water having a specific resistance of about 15,000 cm-ohms at 20°C , pH of 6.5 and 6.0 ppm dissolved O_2 . Evaporation losses are replaced with distilled water.

Test Panels—Hot rolled steel 3-inch x 8-inch x 1/16-inch with a 2-inch vertical scribe mark through the mill scale. The back, edges and water line are covered with "Scotch" electrical tape No. 33 so that an area of 0.1 sq. ft. is exposed.

Electrical Circuit—A rectifier is used with No. 29 platinum wire as an anode. The current flow to each panel is regulated by means of a slide wire resistance and the current flow is measured by the potential drop across a 10-ohm resistor.

Temperature—The temperature of the water is regulated between $25^\circ\text{--}27^\circ\text{C}$ by means of a thermostatic control system using a heat lamp.

Potential Measurement—The potential of the panels are measured using the Pearson D. C. Null Method and in some instances are measured against a stylus tip reference cell.

Although it was the intent to regulate the true potential of the protected panels at the values scheduled, some wide variations in potential occurred, particularly when a heavy building vibration was noted. The potentials of the protected panels were often as much as 150 mv less electronegative than the fairly stable potential of the unprotected panel. The weight loss of the control and the protected panels are shown in Table I.

TABLE I

Panel	Potential Control	Weight Loss	Days
1	No protection	0.90 grams	14
2	-0.60v vs sat. KCl Calomel	0.10 grams	13
3	-0.65v vs sat. KCl Calomel	0.20 grams	10
4	-0.70v vs sat. KCl Calomel	0.05 grams	13
5	-0.75v vs sat. KCl Calomel	0.15 grams	9
6	-0.80v vs sat. KCl Calomel	0.05 grams	14

On panel No. 3 the potential of the scribe line was on occasion observed to be 50 mv less electronegative than the adjoining mill scale when measured with stylus tip half cells. Slight rust formation was noted at the scribe line of panels 2 through 5 whereas the scribe line of No. 1 was covered with rust as well as several random tubercle formations at the weak points of the mill scale.

It is felt that a relatively clean steel surface in contact with a well aerated corroding medium can often be cathodically protected at less electronegative potentials than ordinarily required. The accumulation of soluble alkali developed on the cathodic areas by the supplementary protective current will tend to spread repair of the metal oxide film in the presence of oxygen. Oxide film repair results in the potential of the metal surface being less electronegative or more noble.

Ewing¹ and Evans² have considered this view.

Further work is now underway to determine the behavior of sand blasted steel surfaces at controlled true potentials in well aerated, high resistivity water:

References

1. Scott Ewing. *AGA Proc.*, 613-22, 1940.
2. U. R. Evans, *Met. Alloys*, 62-64, 1931.

Remarks by W. J. Schwerdtfeger, National Bureau of Standards, Washington, D. C.:

Dr. Ewing's results indicate that substantial cathodic protection can be achieved on steel underground even though the structure is not polarized to the potential of -0.85v with respect to the copper-copper sulfate electrode. This is true provided the applied current maintains the potential of the steel at a value equal to or more negative than the average open-circuit potential of the anodes. The average open-circuit potential is not fixed in value but depends upon the chemical and physical properties of the soil and also upon seasonal variations.

The average open-circuit potential of the anodes is usually evidenced by a break in the cathodic polarization curve obtained on the corroding structure. However, it must be borne in mind that pitting can occur under this condition because of the heterogeneity of soil over a considerable area. This is especially true in very alkaline soils where potentials of around -0.85v are possible.

A current equal to or larger than the corrosion current is required to polarize a corroding specimen to the average open-circuit potential of the anodes. In a cathodic protection study with various soils in the laboratory, it was observed that this current was sufficient to cause the potentials of steel specimens to drift to the protective value of -0.85v in a relatively short time. The minimum current required to maintain the protective potential was approximately equal to the corrosion current as calculated from the weight losses of the controls.

Author's Comments:

Dr. Pearson's and Dr. Mears' questions can be answered at the same time. A bridge circuit was not used to measure the potential. It was measured by interrupting the applied current. Of course when this current is interrupted there is a rather rapid change in the potential. The trick is to have a reasonably fast switching arrangement which always acts the same so that the potential can be momentarily observed at a more or less fixed and short time after the break. Experience indicates that an operator can closely duplicate his measurements with this arrangement. We do not see any essential difference

between this method and the bridge method, because the current must be at least partially interrupted to balance the bridge. The error with the switch is always in the same direction, but the error in balancing the bridge may be in either direction.

The best choice between bridge and interrupted circuits probably depends upon the positions of the reference electrodes with respect to the protected structure. The interrupter would probably not work at all on the usual arrangement of reference electrodes on a pipe line when both electrodes are electrically close to the pipe. On a well casing we prefer to have both electrodes rather remote from the casing. The drop between reference electrodes is then usually small and the balance of the bridge is very critical. The interrupter seems to be best for this arrangement.

The discussions of Dr. Sudrabin and Mr. Schwerdtfeger are much appreciated since these men have both carried out experiments similar to the writer's, but with somewhat different methods and different corroding media. It seems reasonable to conclude from the three experiments that steel is always adequately protected in soils and natural waters if it is polarized to -0.85 volt with respect to a $\text{Cu}-\text{CuSO}_4$ electrode. I think that all agree that this must be a true potential measurement; that is, it should not include any IR drop. But the results of these experiments do not agree as to whether it is always necessary to maintain the potential as low as -0.85 volt. This is important because in many well aerated soils, having high resistivity, it is not economically possible to polarize uncoated pipe lines to -0.85 volt; so if this potential is the true criterion of protection, there are many pipe lines on which cathodic protection should not be attempted.

The conclusions of this paper are in general accord with Dr. Sudrabin probably because the experimental methods are very similar. The best explanation we can suggest for Mr. Schwerdtfeger's results is that in his controlled laboratory experiments, the moisture contents and other conditions were near the optimum for maximum corrosion—a condition which certainly was not maintained in our "field" experiments. The question might be settled if it could be shown whether or not it is possible to maintain a steel surface in a passive condition (according to both of Uhlig's definitions in the Corrosion Handbook) with cathodic protection.

Sodium Hydroxide as Inhibitor of Pitting In 18-8 Stainless Steel*

By J. W. MATTHEWS* and H. H. UHLIG**

THE AUTHORS' INTEREST in sodium hydroxide as an inhibitor of pitting began with the observation that this substance in contact with 18-8 stainless steel transforms the noble potential of the passive alloy to a value appreciably more active. Potentials of 18-8, for example, in aerated 4 percent sodium chloride average 0.10 volt noble to Ag-AgCl, whereas after contact with 20 percent NaOH, potentials in the same solution are 0.5 volt more active.¹

Fundamental considerations of the pitting mechanism² lead to the conclusion that pronounced pitting, when observed, is associated with so-called passive alloys and that, on the other hand, in absence of passivity* pitting is less or need not occur at all. Pitting of 18-8 in aerated sea water, for example, occurs because of the large potential difference (approximately 0.5 volt) between a major area of passive alloy, of noble potential, acting as cathode in galvanic contact with a small area, as anode, much more active, (passive-active cell) where passivity has broken down and where practically all corrosion is concentrated (the pit). Furthermore, corrosion products within the pit (e.g., FeCl_2) act to keep this area of metal active and prevent recurrence of passivity. Therefore, if passivity of stainless steels is diminished, as potential measurements prove to be the case when sodium hydroxide comes in contact, the pitting type of corrosion should not occur.

Validity of this reasoning was confirmed, as a matter of fact, by the reported observation that addition of 1 percent sodium carbonate to refrigerating brines in contact with 18-8 stainless steel successfully avoided pitting type of attack for as long as five years.³ It was considered worthwhile to check this observation and to follow the quantitative effect of alkali additions to NaCl solutions over a range of concentrations.

Procedure

When immersed in aerated 4 percent NaCl at 90 degrees C, 18-8 stainless steels pit within a matter of hours.⁴ At this particular temperature and NaCl concentration the pitting rate is highest, hence in the experiments reported herewith these conditions

Abstract

Stainless steels are exceptionally corrosion resistant to many corrosive environments. As a group, however, they possess the weakness of corroding by pitting in aerated solutions of chloride ions. This tendency can be overcome by addition of alkali.

Specimens of 18-8 were subject to an accelerated test at 90 degrees C in 4 per cent NaCl to which increasing amounts of NaOH were added. Without NaOH, an average of 14 pits formed within 24 hours on specimens measuring $5 \times 1 \times \frac{1}{8}$ inch, and corresponding average weight loss was 4.4 mdd. No pitting occurred if the solution contained more than 0.8 percent NaOH. The average weight loss in this concentration of alkali was 1 mdd.

In similar tests conducted at room temperature for 14 months, no pitting occurred in 4 percent NaCl containing at least 0.4 percent NaOH and weight loss was inappreciable. In these tests, it appeared that a more dilute alkali would also have been effective, although such tests have not yet been carried out. The mechanism of inhibition is discussed.

were chosen and a 24-hour period of exposure was adopted as an accelerated test. The specimens of 18-8 Type 304 measured $5 \times 1 \times \frac{1}{8}$ inch. Edges of the specimens were carefully abraded with numbers 40 and 120 metallurgical belts, a procedure which was obligatory because most of the corrosion pits occur on the edges. (Predominance of corrosion at the edges probably owes to preferred crystal orientation brought about by rolling such that exposed crystal faces at edges have greater corrosion tendency compared with faces parallel to the surface.⁴) Despite corrosion largely at edge pits, actual weight loss determinations for specimens whose area varied 3 to 5 fold showed that corrosion was strictly proportional to total specimen area. For this reason it was possible to report rates of corrosion despite the fact that corrosion was highly localized. This fact also suggested that control of the rate is at the cathode areas made up of all the specimen surface excepting the negligible area of the pits. In other words, it is at cathodes that oxygen depolarization occurs at a rate proportional to the amount of oxygen reaching the specimen which in turn controls the rate of metal solution at the anodes or pits.

Specimens were cleaned in boiling acetone and benzene, and were given a final dip in 20 percent HNO_3 at 60 degrees C. After the test, they were scrubbed in water followed by immersion in boiling alcohol.

The alloy analyzed 18.6 percent Cr, 8.5 percent Ni, and 0.06 percent C.

Tests were carried out in a Pyrex jar measuring

* A paper presented at the Seventh Annual Conference and Exhibition, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951.

* Creole Petroleum Corp., Refinery Dept., Caripito, Venezuela.

** Corrosion Laboratory, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

† Passivity associated with a comparatively noble potential according to definition 1, Corrosion Handbook, P. 21, John Wiley & Sons, Inc. (1948).

6 inches in diameter x 12 inches high, with ground edge over which a glass cover with ground under-surface fitted tightly (Figure 1). A glass condenser was mounted through a hole in the center of the cover, and glass hooks served to hold the test specimens. The solutions were made up using chemically pure sodium chloride, distilled water, and sodium hydroxide, the latter prepared by cooling a concentrated hot solution of sodium hydroxide in order to separate out most of the contaminating sodium carbonate.

Air purified over soda-lime entered through a tube inside the condenser tube at 85 ml per minute, a rate determined previously as being outside critical velocities affecting the corrosion rate.⁴ This rate was ample to keep the solution saturated with air and well stirred. A glass chimney resting on the bottom of the jar prevented bubbles of air from making contact with the specimens. The jar was immersed in an oil thermostat controlled within ± 0.3 degree C. Three specimens were exposed at a time in a given solution; from their average weight loss an average corrosion rate was calculated. In addition, a dental probe was used to help locate and count the reported number of pits.

Discussion

Each point, therefore, presented in Figure 2 is an average of three specimens. Reproducibility from one specimen to the next was typical of corrosion tests in which pitting is the predominant form of corrosion and, hence, fell below reproducibility obtainable with non-passive and uniformly corroding metals like steel or copper in salt solutions. A typical series of weight losses for individual specimens, exposed at the same time, is the following:

Specimen	Corrosion Rate in 4% NaCl (90° C, 24 Hr. test)	No. of Pits per Specimen
	mdd	
A	4.8	20
B	4.5	17
C	3.9	14

Data of Figure 2 show that no visible pitting occurred when sodium hydroxide was present to the extent of 8 grams per liter of 4 percent NaCl (approximately 0.8 percent NaOH). Overall corrosion rate was 1 mdd at 0.4 percent NaOH, dropping to 0.4 mdd at 8 percent NaOH. The same conclusions were drawn from tests conducted for a period of one week instead of 24 hours. In other words, no pitting occurs within one week and probably longer if sodium hydroxide is added to the extent of at least 0.8 percent.

Above 80 grams of NaOH per liter (not shown in Figure 2) it was found that the corrosion rate increases, reaching about 2.4 mdd at 200 grams NaOH per liter, but still without incidence of pitting.

Potential Measurements and Room Temperature Runs

It was thought worthwhile to establish that the accelerated test results can be applied practically to long-time exposures. Specimens of 18-8 of similar size to those used above were partially immersed in stagnant 4 percent sodium chloride solutions containing various additions of sodium hydroxide. These

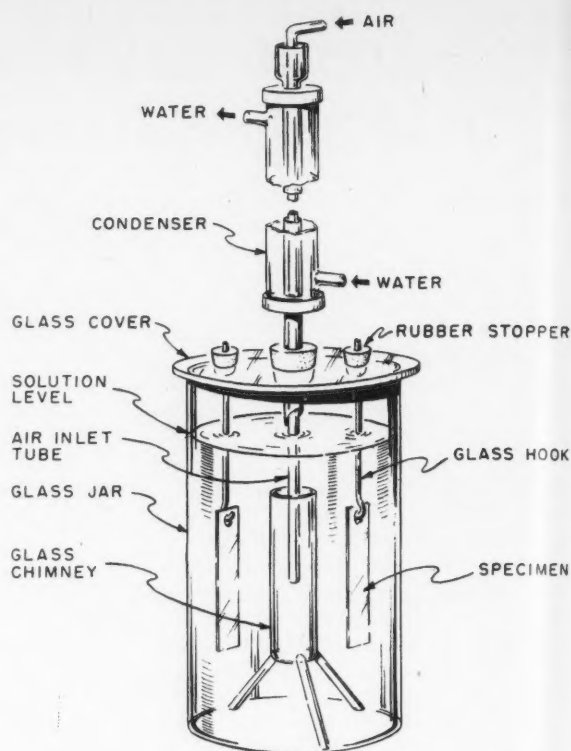


Figure 1—Corrosion test jar.

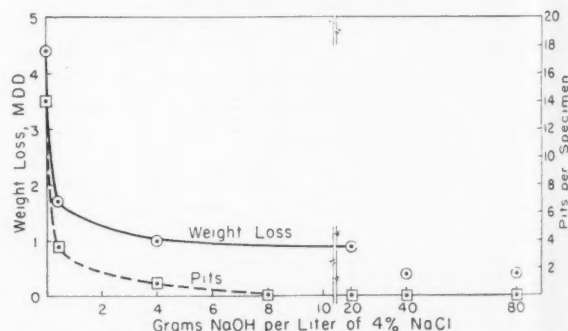


Figure 2—Effect of NaOH in 4 percent NaCl on weight loss and pitting of 18-8, 24-hour test, 90 degrees C.

specimens were tested for 14 months under these conditions, distilled water being added as needed. At the end of this time, one specimen had pitted in the solution free of NaOH. The two pits for this specimen, were actually first observed two weeks after the test began. Neither the companion specimen nor any of the specimens immersed in alkaline sodium chloride pitted for the duration of the test. The specimens in the more concentrated alkaline solutions tarnished perceptibly, but the maximum weight loss after removal of the tarnish with nitric acid was negligible (0.006 mdd). It is possible in these experiments that silicates had formed by slow reaction of the glass container with sodium hydroxide, and that these may have served as additional corrosion inhibitors.

Potential measurements conducted by Arthur Geary of this laboratory, showed that 18-8 in 4 per-

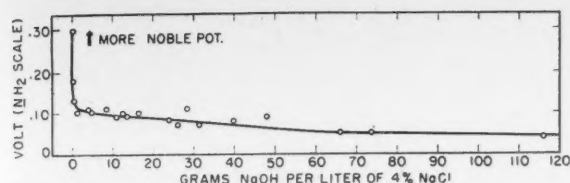


Figure 3—Effect of NaOH additions on potentials of 18-8 in 4 percent NaCl at 25 degrees C.

cent sodium chloride, as expected, rapidly became less noble even when small amounts of sodium hydroxide were added. The data of Figure 3 are steady-state values at 25 degrees C after approximately 100 hours. Potentials of 18-8 in 4 percent NaCl containing as little as 1 gram of NaOH per liter were 0.2 volt more active than in 4 percent NaCl without alkali.

The data show, therefore, that the passive-active cell in the pitting reaction operates at a maximum of approximately 0.3 volt in alkaline NaCl compared with 0.5 volt otherwise. This in part explains lack of pitting in alkaline sodium chloride at room temperatures, and probably also at 90 degrees C in 4 percent NaCl containing more than 0.8 percent sodium hydroxide.

In addition, another factor enters because the hydroxyl ion is more mobile than the chloride ion. The limiting conductance of OH^- , for example, is $198 \text{ ohm}^{-1}\text{-cm}^2$, whereas for Cl^- it is $76.3 \text{ ohm}^{-1}\text{-cm}^2$. Therefore, OH^- will migrate more rapidly than Cl^- toward the anode during the corrosion reaction. This means that in neutral NaCl any incipient anode area or pit is immediately bathed in alkali, thereby precipitating as hydrous oxides the acid passivity-destroying products such as FeCl_2 . Accordingly, the pitting action which commonly continues at an increased rate because acid anodic products produce more anodic surface, is stifled in presence of alkali. Oxygen, consequently, can then diffuse more easily to anodic areas and restore passivity, contrary to the situation when FeCl_2 surrounds the anode. Once passivity of the anode is restored, anodes and cathodes are again at the same potential and the passive-active cells responsible for pitting no longer operate.

It follows that pitting of 18-8 is not expected for any period of exposure to sodium chloride provided alkali concentration is continuously maintained at the required level over all the surface.

Summary

Eighteen-Eight stainless steel exposed to aerated 4 percent NaCl at 90 degrees C corrodes by visible pitting within a few hours. A minimum of 0.8 percent sodium hydroxide inhibits pitting. At room temperature, sodium hydroxide additions also suppress pitting in brines.

The pitting mechanism results from galvanic action between a major surface of passive metal acting as cathode and a small active area of metal acting as anode (the pit). Potential measurements show that NaOH depresses the noble potential of passive 18-8, hence diminishing the operating potential of the passive-active cell. In addition, the fast moving hydroxyl ion reacts with any passivity-destroying corrosion products such as FeCl_2 at the anode, thereby stifling the chain reactions that initiate pitting.

References

1. H. H. Uhlig. *Trans. Am. Inst. Min. & Met. Engrs.*, **140**, 387 (1940).
2. H. H. Uhlig. *Trans. A.I.M.E., Iron & Steel Div.*, **140**, 411-432 (1940).
3. P. Schafmeister and W. Tofaute. *Tech. Mitt. Krupp*, **3**, 223 (1935).
4. H. H. Uhlig and M. C. Morrill. *Ind. Eng. Chem.*, **33**, 875 (1941).

DISCUSSION

Question by J. Pat Casey, Jr., Crane Company, Chicago:

As the data presented were obtained in a 4 percent NaCl solution, what effect would an increase in the salt concentration have on the amount of NaOH required to obtain effective inhibition of the stainless steel?

Authors' Reply:

We did not extend our investigation to sodium chloride concentrations other than 4 percent by weight. It may be worth mentioning that 3 to 4 percent NaCl represents the most corrosive concentration, so that one might expect the conditions of inhibition to be somewhat less, rather than more of a problem at other concentrations.

Question by Clifford B. Armstrong, Wyandotte Chemicals Corp., Wyandotte, Mich.:

The data showed the active condition of stainless steel corrodes more slowly than the passive condition. Why is this?

Authors' Reply:

The real reason is that galvanic cells largely responsible for corrosion are absent when the stainless steel exhibits an active potential contrasted with the situation when the potential is noble. When stainless steels exhibit a noble potential and chlorides are present at the same time, it is possible for passive-active cells to initiate with an operating potential difference of about 0.5 volt. This large potential difference accounts for very rapid attack at the areas where passivity has broken down locally, causing pitting. However, when the potential behavior of stainless steels is affected by alkali additions, the passive-active cells can no longer establish themselves, or if they do the operating potential is much less. In addition, the hydroxyl ion serves to precipitate out any corrosion products at the anode which normally cause breakdown of passivity, thereby helping to produce an electrochemically uniform surface with less tendency to corrode.

Discussion by W. G. Renshaw, Allegheny Ludlum Steel Corp., Brackenridge, Pa.:

We would like to mention here some practical experience we have had with the use of sodium hydroxide as an inhibitor of pitting in 18-8 stainless steel by sea water or brines. Some years before World War II three Navy destroyers were equipped with 18-8 stainless steel gasoline storage tanks having

special sodium hydroxide injector valves attached. These injector valves were installed in such a way that when the main inlet valves were opened, a measured amount of sodium hydroxide was simultaneously run into the tank along with the sea water in order to keep the pH sufficiently alkaline to avoid pitting.

While we were able to follow these tests for several years, unfortunately, we lost track of the destroyers during the war and believe they have now been scrapped. At the last report, the tanks had been in service for several years with no instances of pitting where sodium hydroxide had been added.

In connection with brine solutions in the 18-8 stainless steels, we have also found that such hydroxide additions have been quite effective in preventing pitting, particularly in cases where the brines are allowed to lie stagnant in contact with stainless steel equipment for any periods of time.

Discussion by C. S. Brown, General Aniline & Folm Corp., Grasselli, N. J.:

My question arose when Dr. Uhlig intimated in response to a question from the floor that corrosion would have been less if no air were bubbled through his solution. I asked him if it were not true that corrosion in sea water is aggravated under stagnant conditions. The chairman attached another question to mine.

Under stagnant conditions, microorganisms or inanimate matter accumulates in localities. An oxygen cell then is set up where the covered areas, poor in oxygen, are anodic to the much larger free areas, rich in oxygen. Due to the strong electrolytic properties of sea water, appreciable pitting can, and does, take place.

Under rapid flow conditions, these accumulations are removed by the motion of the water and corrosion is more nearly uniform.

T
try
me
tre
we
cor
an
any
?
high
into
we
for
stre
nev
bee
allo
the
the
tion
man
Wr

T
ciat
lar.
the
of r
finis
prob
be d
In
ing a

★ A. D.
ASSO
1949

Corrosion Aspects of Fusion Welded Aircraft High-Strength Aluminum Alloys*

By LOREN W. SMITH

Introduction

THE CORROSION characteristics of aluminum and aluminum alloys for use in the aircraft industry are of prime importance. Aeronautical requirements dictate the use of special high-strength, heat-treated alloys with the highest ratio of strength to weight possible, but with a very high resistance to corrosion owing to the low factors of safety employed and to the comparatively thin sections involved where any loss of thickness becomes relatively serious.

The corrosion aspects of fusion welded joints of high-strength aluminum alloys have become of special interest due to the recent development of improved welding processes, such as Multi-arc and Heliarc for the joining of aluminum alloys. Very high joint-strength efficiencies are now obtainable with these new welding methods. Several corrosion studies have been carried out on fusion welded 24S, 61S and 75S alloys by the Cornell Aeronautical Laboratory over the past several years, and this paper summarizes the important data resulting from these investigations, which were sponsored by Air Material Command, AAF, BuAer, Navy Department and Curtiss-Wright Corporation.

Scope of Investigations

There are two types of corrosion commonly associated with aluminum alloys: pitting and intergranular. Of these, only the last one is of real concern for the successful maintenance of the airplane. The use of relatively pure aluminum cladding and protective finishes have reduced the pitting type of corrosion problem to insignificance. In addition, this type can be detected usually in service by visual inspection.

Intergranular corrosion and stress corrosion cracking are known to be associated with the heat effects

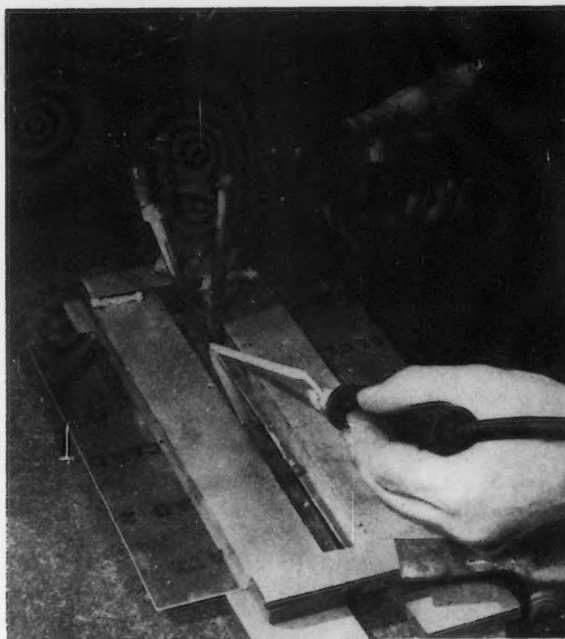


Figure 1—Multi-arc welding setup.

LOREN W. SMITH has been head of the Metallurgical Section of the Cornell Aeronautical Laboratory at Buffalo, N. Y., since its establishment as the Curtiss-Wright Airplane Division's Research Laboratory in 1942. Previously he was head of Curtiss-Wright's Kenmore, N. Y., plant materials laboratory. He has held positions with General Motors, Chevrolet Division; Linde Air Products Research Laboratory, Dupont Cellophane Division and American Radiator Co. Aircraft metallurgical research has been his principal field for ten years. He attended University of Buffalo and Canisius College, graduating with a BSc degree from the latter in 1935.



Abstract

While the mechanical joint strength efficiencies of fusion welded high strength aluminum alloys have been considerably improved by new welding processes, the uncertainty of the lowered corrosion resistance of the welded alloys due to the deleterious effect of the heat involved has been a major obstacle to the extended use of welded aluminum alloys of the 24S and 75S types for aircraft structures.

This article discusses the metallurgical structures resulting from the fusion welding of aluminum alloys and correlates these structures with the resulting corrosion data. The results of several investigations on the corrosion resistance of fusion welded 24S, 61S and 75S aluminum alloys are reported. Tensile strength comparisons of bare and clad welded alloys exposed to corrosive mediums in the as-welded, aged and reheat treated conditions are made.

The protective value of cladding and the restoration of the original parent metal structure by reheat treatment are demonstrated by the accumulated corrosion data for the high strength wrought aluminum alloys used in aircraft construction.

Conclusions from these laboratory and outdoor exposure corrosion studies are made and recommendations are offered for the fusion welding of the high strength aluminum alloys with the optimum corrosion resistance.

* A paper presented at the Fifth Annual Conference of the National Association of Corrosion Engineers, Cincinnati, Ohio, April 11-14, 1949.

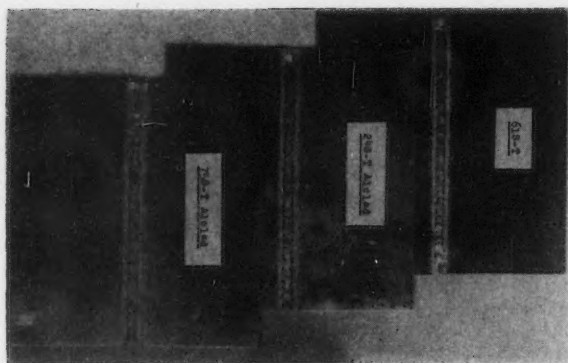


Figure 2—Typical welded panels of 61S-T6, 24S-T4 and 75S-T6.

on aluminum alloys. The reports of Rawdon,¹⁻⁶ Dix,⁷⁻⁸ Mutchler,⁹ Arrowsmith and Murray,¹⁰ as well as those of many others, cover investigations made on the corrosion of high-strength aluminum alloys as influenced by heat treatment. Correlating these studies with the welding temperatures involved to produce fusion of the aluminum alloys being welded, it becomes apparent that corrosion is a major consideration for the successful application of welded high-strength aluminum alloys.

The Multi-arc process, which has been described in the literature,¹¹ was used in the welding of all test panels because of its adaptability to the welding of aluminum sheet alloys. This process uses twin carbon electrodes carrying AC current and a filler rod carrying DC current. Close temperature control makes the welding of aluminum sheet as thin as .016-inch possible. Figure 1 shows the Multi-arc

welding setup. Figure 2 shows typical welded plates from which tensile and corrosion specimens were cut.

The investigations conducted were mainly concerned with 24S and 75S alloys. These two alloys represent the two main classes of high-strength aluminum alloys commonly in use at the present time. The data on 61S are presented for comparison with the 24 and 75S alloys because this alloy is commonly accepted as a safe welding alloy from the point of view of resulting corrosion characteristics.

The evaluation studies were conducted on a laboratory acceleration basis and also were correlated with some outdoor exposure tests. Results from additional outdoor exposure of a marine nature by the National Bureau of Standards are also available.

The corrosion characteristics of each alloy are reported separately.

24S Alloy

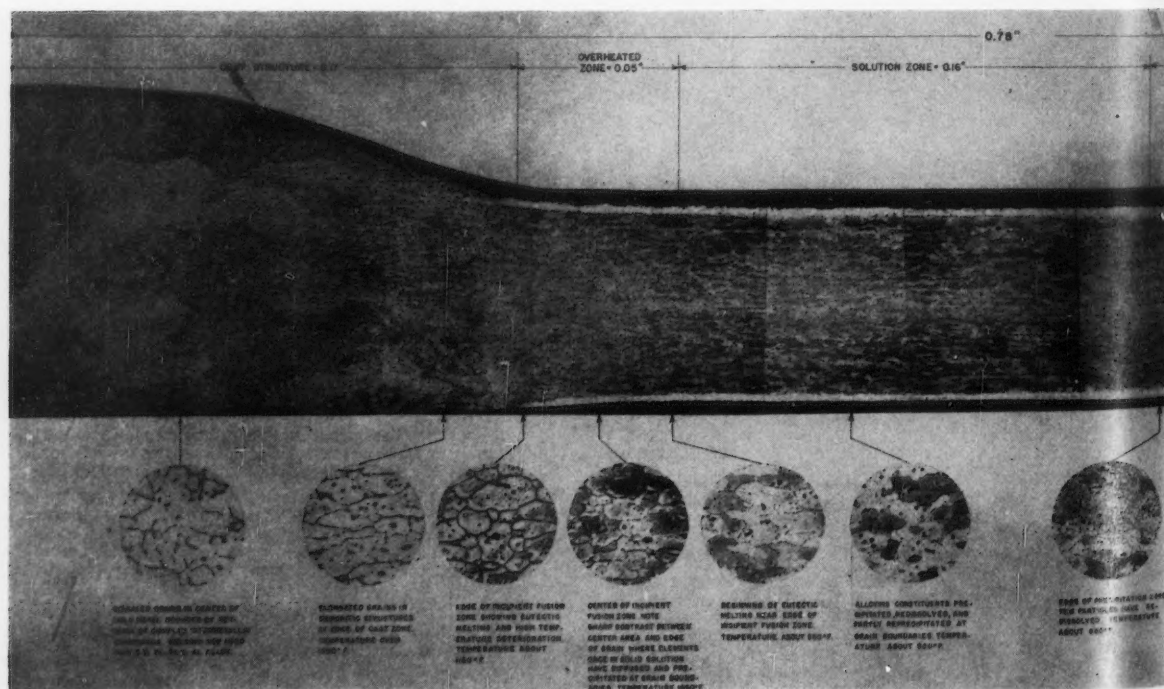
The corrosion studies on the effects of welding the copper-magnesium-manganese aluminum base alloy known as 24S included the determination of susceptibility of intergranular corrosion and stress corrosion cracking in the as-welded, aged and re-solution and aged conditions. Both bare and clad 24S alloys were evaluated.

Metallurgical Structure of the Weld

Since corrosion resistance is contingent upon the metallurgical characteristics of the 24S alloy, it is desirable to discuss the metallography of the weld and the adjoining parent sheet before reporting on the corrosion testing.

The major part of the parent metal used in these studies was 0.064-inch Alclad 24S-T4. Various weld-

Figure 3—Micro-map of Multi-arc weld of Alclad 24S-T4. Assembly-Magnification approx. 52X; Circles, approx. 340X.



ing rod compositions were used ranging from the commercially available 43S, a 5 percent Si, 95 percent aluminum alloy to those specially developed by the Cornell Aeronautical Laboratory for the joining of 24S and 75S aluminum alloys with high-joint strength efficiency. This development of high-strength welding rods for the heat-treatable aluminum alloys was sponsored by the BuAer, Navy Department under Contract NOa(s) 8180.

When 0.064-inch Alclad 24S-T4 sheet is welded by the Multi-arc process, the microstructure of the metal is affected by the heat of the arc for a distance of approximately 0.66-inch on either side of the center line of the weld. The heat-affected structure consists of four distinct zones, each zone merging gradually at its outer boundaries into the adjoining zones. Figure 3 is a photographic reproduction of a series of overlapping photomicrographs taken of these zones. Only one side of the joint is shown.

The cast or fusion zone at the left refers to that portion of the bead which was molten during the welding process. It includes filler metal from the welding rod and parent metal from the butt ends of the welded sheet. Roughly 0.35-inch of parent sheet becomes molten and alloys with the filler rod when 0.064-inch sheet is welded by this process.

The second zone shown in Figure 3 is the overheated or partial fusion zone which has an approximate width of 0.05-inch on either side of and adjacent to the cast structure. The characteristic microstructures associated with this zone are enlarged grains and melted eutectic at grain boundaries and within grains.

The solution zone is approximately 0.16-inch wide and occurs where the temperatures have reached above 900 degrees F but below the eutectic melting temperature of 940 degrees F. Particles of alloying

constituents precipitate from solid solution and then re-dissolve as the temperature increases. A small amount of the dissolved phase again precipitates at grain boundaries as the temperature recedes from its maximum height. The rate of cooling is slower than that produced by a water quench, as this grain boundary precipitation shows. It is probably somewhat faster than that of cooling in air, due to the conduction of heat to the cooler portion of the parent sheet.

In the next zone, which has been called the precipitation or coalesced zone, the temperature at the center has caused dissolved constituents to precipitate and sub-microscopic particles to coalesce so as to become visible in the microscope. The temperature does not become sufficiently high to cause re-resolution of these particles. Upon etching with Keller's etch, the precipitation zone becomes darkened sufficiently to be easily distinguished from the solution zone with the naked eye. It is very difficult, however, to mark the junction where the precipitation zone merges with the unaffected structure of the parent sheet. As nearly as can be determined with a microscope, this precipitation zone appears to be approximately 0.28-inch wide.

Accelerated Intergranular Corrosion Testing

Intergranular corrosion in aluminum alloys such as 24S results from an electrochemical action which takes place under certain conditions. The conditions necessary to produce intergranular corrosion in 24S aluminum alloys are as follows:

1. The aluminum-copper solid solution at the grain boundaries must be somewhat depleted in copper content, the copper being precipitated in the form of CuAl_2 or other intermetallic.
2. An electrolyte must be present. This may be in the form of atmospheric condensation, ocean spray, salt water, etc.

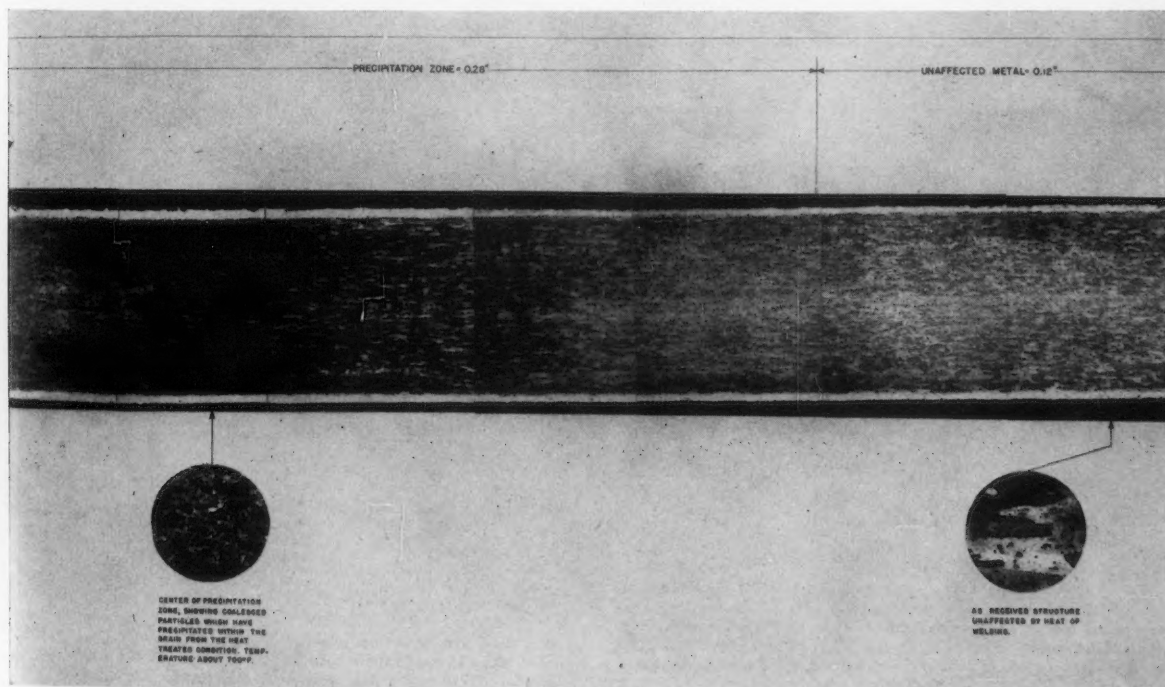


TABLE I
Loss of Ultimate Joint Strength of Welded .064-Inch 24S-T Alclad
By Corrosion in H₂O₂-NaCl Solution

Rod Heat No.	Heat Treatment Condition	Five Periods ¹		Ten Periods		Fifteen Periods	
		Without Tygon ²	With Tygon	Without Tygon	With Tygon	Without Tygon	With Tygon
10	As Welded.....	7.6%	10.4%	39.2%	18.4%	69.2%	37.1%
9	As Welded.....	2.4	6.5	32.7	13.0	40.0	33.4
34	As Welded.....	8.9	10.5	9.9	20.6	10.0	26.2
8	As Welded.....	5.2	4.4	27.8	14.6	100.0	25.7
37	As Welded.....	10.6	4.8	37.3	10.3	55.7	33.8
32	Aged.....	31.7	33.9	32.3	43.3	40.0	45.9
23	Aged.....	16.7	5.5	28.7	12.8	38.6	9.4
33	Aged.....	30.1	26.8	38.8	30.8	35.8	39.5
37	Aged.....	16.4	11.9	15.6	9.9	19.4	22.3
22	Aged.....	28.0	11.5	27.7	9.4	29.9	14.6
31	Solution Treated and Aged ³	13.2	17.3	33.1	24.9	46.0	31.1
8	Solution Treated and Aged	63.7	20.3	93.0	17.0	84.2	38.4
24	Solution Treated and Aged	23.8	49.0	49.4	41.4	57.9	31.0
6	Solution Treated and Aged	35.4	12.5	80.2	33.6	76.4	58.4
11	Solution Treated and Aged	16.4	18.3	19.8	14.5	47.8	25.3
24S	Solution Treated and Aged	23.9	12.8	24.1	12.9	37.1	27.8

Note 1—One Period (One period equals six hours of exposure in the standard intergranular corrosion, H₂O₂-NaCl Solution.)

Note 2—Tygon (Specimens with Tygon paint had all surfaces covered except the weld bead.)

Note 3—Heat treatment consisted of 920° F. for one half hour, cold water quenched, and aged at 350° F. for 8 hours.

TABLE II
Chemical Composition of Filler Rod Heats

Heat No.	Analysis: (Calculated: Balance Aluminum)					
	Zinc	Magnesium	Chromium	Silicon	Titanium	Others
2	5.0	.5	.5	....	.2	.25B
3	5.0	.5	.5	....	.2	.4Ce
4	5.0	.5	.5	....	.2	1.0Ce
5	5.0	.5	.5	....	.2	2.0Ce
6	5.0	.5	.5	1.0	.2	1.0Ce
8	5.0	.5	.5	4.0	.2	....
9	5.0	.5	.5	6.0	.2	....
10	5.0	.5	.5	8.0	.2	....
11	5.0	.5	.8	....	.2	.4Ce
12	5.0	.5	.8	....	.2	....
14	5.0	.5	2.5	....	.2	....
17	5.0	.5	.5	....	.2	1.0Bi
19	5.0	.5	.5	....	.2	1.0Ge
20	5.0	.5	.5	....	.2	1.0Hg
21	5.0	.5	.5	....	.2	1.0Sb
22	..	....	....	5.0	....	.6Ca
23	..	....	....	5.0	....	2.0Ca
24	..	1.0	....	5.0	....	1.0Ge
31	..	....	....	5.0	....	2.5Cu
32	5.0	.5	.5	10.0	.2	....
33	5.0	.5	.5	12.0	.2	....
34	5.0	.5	.5	14.0	.2	....
37	..	1.0	....	7.0	....	4.9Cu

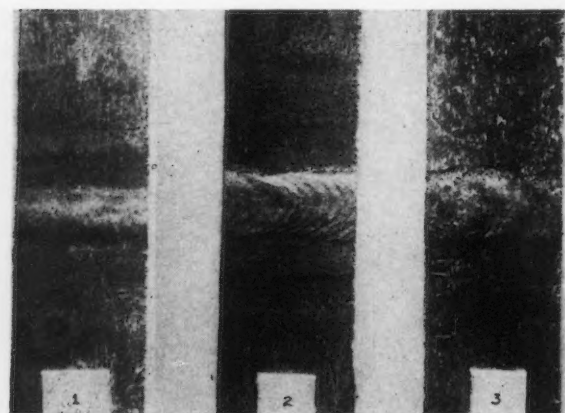


Figure 4—24S bare .064-inch thick welded with 43S rod after intergranular corrosion test of the salt-peroxide solution for six hours. 1—as welded, 2—aged at 350 degrees F for eight hours, 3—solution treated at 920 degrees F, cold water quenched, aged at 400 degrees F for 16 hours. Approximately same size.

A galvanic action is set up between the depleted aluminum-copper solid solution at the grain boundaries and the richer aluminum solid solution of the grain plus the precipitated copper aluminum compound particles. Since the area along the grain boundaries is anodic, that is, the flow is from the grain boundary to the grain and the precipitated particles, this area dissolves out, thus producing intergranular corrosion.

In properly heat-treated 24S aluminum alloy, the susceptibility to this type of corrosion does not exist, since the copper is in solid solution in the aluminum and there are no depleted anodic areas at

the grain boundaries. However, when the alloy is not quenched rapidly after heat treatment or when it is reheated to temperatures below solution for short periods,

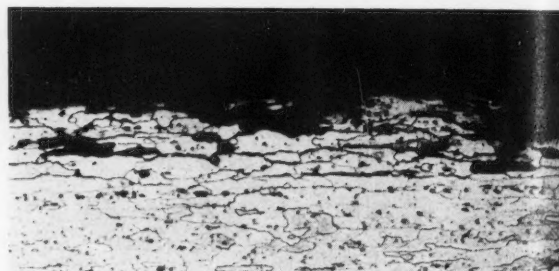


Figure 5—Typical intergranular corrosion of as-welded bare 24S-T6 sheet welded with 43S rod. Area is in solution zone of heat affected parent metal. Keller's etch, 100X. Test was in salt-peroxide solution for six hours.

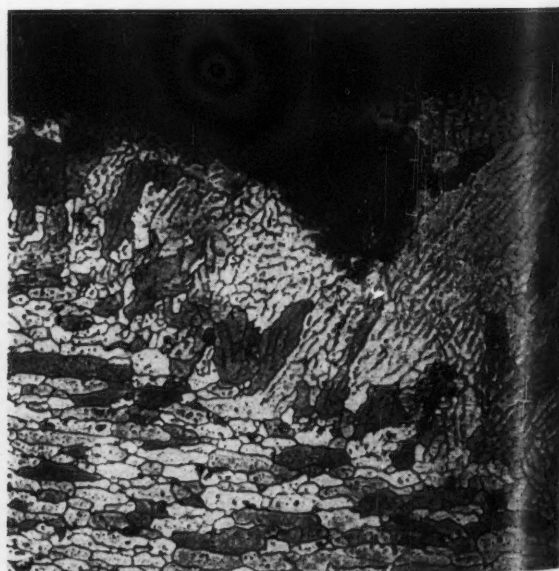


Figure 6—Corrosion at junction of weld and sheet of bare 24S-T6 welded with 43S rod in the reheat treated condition. Keller's etch, 100X. Test was in salt-peroxide solution for six hours.

the copper aluminum compound particles are precipitated or coalesced with depleted grain boundaries and intergranular corrosion may occur.

In most fusion welding processes, the heat of fusion causes changes in the microstructure of the metal that are responsible for lowered corrosion resistance. In the heat affected areas, the resistance to intergranular corrosion is greatly lowered. When the welds are reheat-treated and properly quenched, the copper precipitates are re-dissolved and the microstructures restored to their original condition, except in the over-heated zone where eutectic melting has occurred.

Intergranular corrosion evaluation of welded bare and clad 24S-T4 sheet was conducted in the "as-welded," aged at 350 degrees F for 8 hours, and re-solution treated and quenched specimens aged at various temperatures for various lengths of time. Accelerated corrosion tests were performed in strict accordance with procedures described in the AN-QQ-H-186a specification. This consisted of an etching by immersion in a HNO_3 -HF solution to produce a uniform surface condition followed by a rinse, then an immersion in concentrated nitric acid followed by a rinse and dry. The specimens were corroded by immersion in approximately 30 ml per square inch of surface area of a solution of the following composition.

NaCl		57 gms.
H_2O_2	30% C. P.	10 ml
Diluted to 1 liter with distilled H_2O		

Figure 4 shows the surface of 24ST bare .064-inch welded with 43S rod after intergranular corrosion test as described in AN-QQ-H-186a. Specimen 1 is in the as-welded condition and shows the heaviest attack in the precipitation zone. Specimen 2 has been aged at 350 degrees F for 8 hours after welding and also shows considerable attack in the precipitation zone. Specimen 3 which was solution treated at 920 degrees F, cold water quenched, aged at 400 degrees F for 16 hours, shows no attack in the precipitation zone; however, there is some attack at the junction of the weld bead and sheet.

Figure 5 shows the intergranular nature of the attack in the precipitation zone of Specimen 1 shown in the previous Figure. Figure 6 shows the corrosion in the junction of the weld bead and sheet of Specimen 3 shown in Figure 4. Figure 7 shows the nature of the corrosion occurring on the weld bead itself of Specimen 3. Figure 8 shows very slight corrosion occurring in the solution zone of Specimen 3, which was the reheat-treated specimen. This is considerably less severe than the attack shown in the as-welded condition.

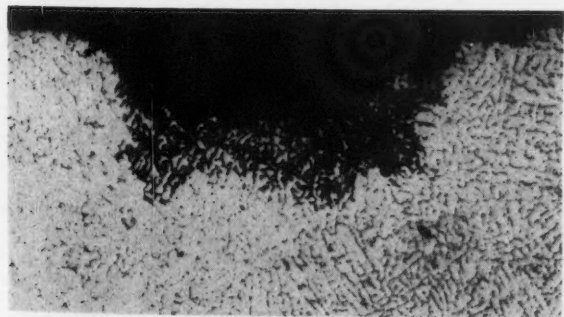


Figure 7—Corrosion on weld bead of bare 24S-T6 welded with 43S rod in the reheat treated condition. Keller's etch. 100X. Test was the salt-peroxide solution for six hours.

The protective value of Alclad is demonstrated in Figure 9. Two as-welded 24S-T4 specimens, one Alclad and one bare, were corroded in the standard

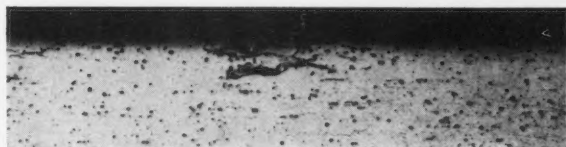


Figure 8—Very slight corrosion in solution zone of 24S-T6 bare welded with 43S rod in the reheat treated condition. Unetched. 100X. Test was the salt-peroxide solution for six hours.

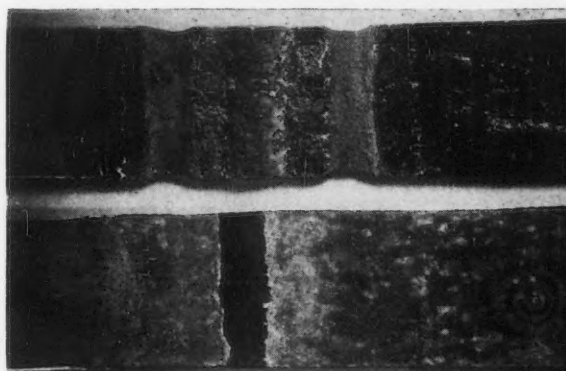


Figure 9—Comparison of intergranular corrosion attack on welded bare and clad 24S-T in the as-welded condition. The attack on the bare specimen has occurred in the precipitation zones. The clad on the other specimen has prevented attack. Exposure was to NaCl - H_2O_2 solution for 72 hours.

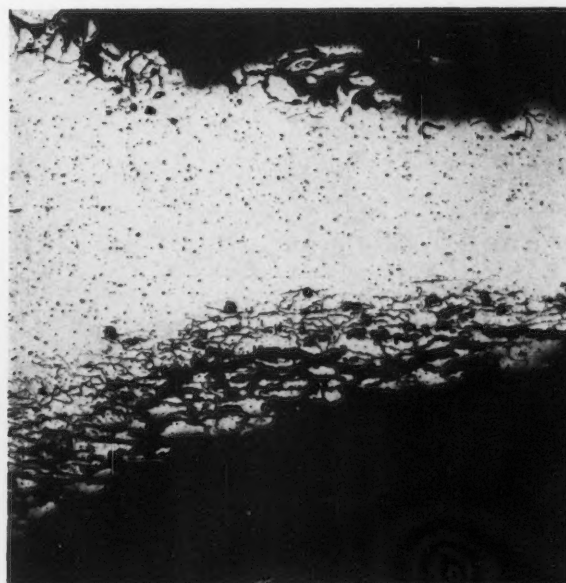


Figure 10—Transverse section through corroded precipitation zone of bare specimen shown in Figure 9. Unetched. 100X.

NaCl-H₂O₂ solution. The H₂O₂ was not replenished once the test was started. The bare 24S-T4 showed extremely heavy attack in the precipitation zone, while the Alclad specimen was unattacked. Figures 10 and 11 show transverse sections through the precipitation zones of the bare and Alclad specimens after exposure. The Alclad coating will afford protection to the weld and core metal until such time as an appreciable portion of the coating has been removed by corrosion.

To make a breakdown corrosion test on clad sheet alloys, the corrosion conditions were made more severe than the standard laboratory tests called for by the specification, which is a six hour exposure. Welded specimens of Alclad 24S-T4 and Alclad 75S-T6 were prepared in the three heat-treat conditions and immersion in a solution of H₂O₂-NaCl for 30, 60 and 90 hours. The H₂O₂-NaCl solutions were replenished with H₂O₂ every six hours, since this constituent loses its potency after this time interval. Each six hours of immersion can be termed one period.

Two different types of specimens were used in loss strength. One type had all the surfaces, except the weld bead, coated with rubber base Tygon paint to limit the corrosion action to the bead. The other type

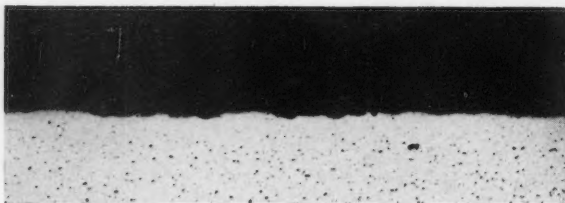


Figure 11—Transverse section through precipitation zone of the Alclad specimen shown in Figure 9. The core metal is intact due to the protection offered by the cladding. Unetched, 100X.

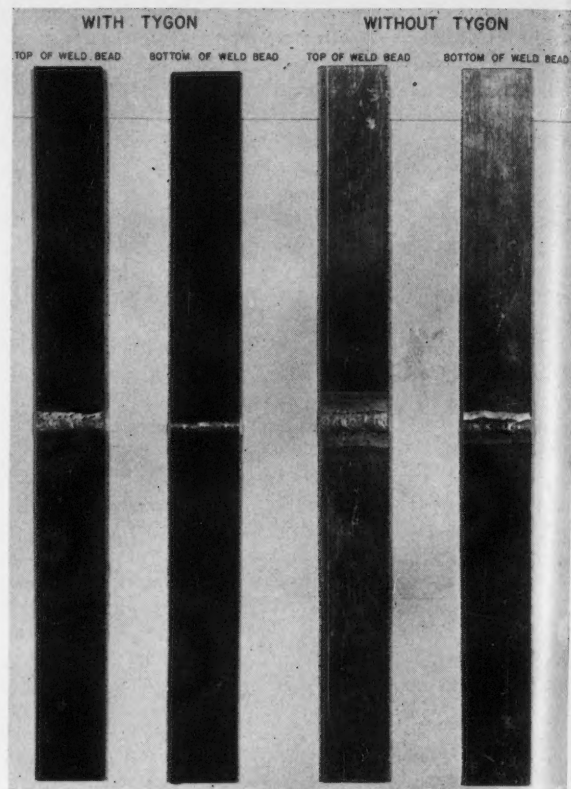


Figure 12—The two types of specimens used in the loss of strength corrosion tests. The corrosion of the Tygon (rubber base) painted specimens was confined to the weld bead while the corrosion of the unpainted specimens was free to take place at any point, according to the potential conditions present.

TABLE III
Outdoor Weather Corrosion of Multi-Arc Welds
(Buffalo, N. Y., Semi-Industrial Atmosphere)

Specimen No.	Alloy	Rod Alloy		ULTIMATE JOINT STRENGTH				Percent Loss Original vs 29 Months
				No Exposure	6 Months	12 Months	29 Months	
1	3S $\frac{1}{2}$ H	5% Si	As Welded *	16,480	13,480	15,900	15,900	3.5
2	24S-T bare	5% Si	As Welded	44,100	40,250	43,300	36,800	16.5
3	24S-T bare	5% Si	920° F, $\frac{1}{2}$ hr., H ₂ O, R. T. age	54,000	54,800	47,800	57,200	+5.9
4	24S-T bare	Zn-Mg	As Welded	47,100	39,200	40,500	36,300	23.0
5	24S-T bare	Zn-Mg	920° F, $\frac{1}{2}$ hr., H ₂ O, R. T. age	55,100	54,800	48,100	56,400	+5.5
6	24S-T Alclad	5% Si	As Welded	47,500	47,200	45,800	45,200	4.7
7	24S-T Alclad	5% Si	920° F, $\frac{1}{2}$ hr., H ₂ O, R. T. age	56,600	53,900	59,250	58,200	+2.8
8	24S-T Alclad	Zn-Mg	As Welded	30,500	43,600	47,400	47,000	+54.0
9	24S-T Alclad	Zn-Mg	920° F, $\frac{1}{2}$ hr., H ₂ O, R. T. age	63,000	59,250	47,600	61,000	3.2
10	52S- $\frac{1}{2}$ H	5% Si	As Welded	29,200	27,400	27,600	27,800	4.7
11	52S- $\frac{1}{2}$ H	Zn-Mg	As Welded	29,500	27,700	28,100	28,300	2.7
12	R-301-T clad	5% Si	As Welded	45,600	43,900	42,500	44,400	2.6
13	R-301-T clad	5% Si	320° F, 18 hr.	48,000	46,300	46,200	46,500	3.2
14	R-301-T clad	5% Si	940° F, $\frac{1}{2}$ hr., H ₂ O, 320° F, 18 hr.	65,900	58,900	55,400	54,700	17.0
15	R-301-T clad	Zn-Mg	As Welded	42,600	47,200	39,700	43,600	2.3
16	R-301-T clad	Zn-Mg	320° F, 18 hr.	47,800	46,600	45,300	44,500	6.9
17	R-301-T clad	Zn-Mg	940° F, $\frac{1}{2}$ hr., H ₂ O, 320° F, 18 hr.	66,750	66,100	66,600	62,600	6.2
18	75S-T clad	Zn-Mg	As Welded	55,600	58,800	58,000	56,800	+3.6
19	75S-T clad	Zn-Mg	250° F, 24 hr.	57,800	43,800	57,900	56,100	2.9
20	75S-T clad	Zn-Mg	920° F, $\frac{1}{2}$ hr., H ₂ O, 250° F, 24 hr.	81,750	78,500	79,000	36,400	55.7
21	75S-T clad	5% Si	As Welded	50,900	52,600	43,500	47,300	7.1
22	75S-T clad	5% Si	250° F, 24 hr.	47,000	54,250	55,600	53,300	+13.4
23	75S-T clad	5% Si	920° F, $\frac{1}{2}$ hr., H ₂ O, 250° F, 24 hr.	54,000	52,400	53,400	40,000	26.0
24	75S-T bare	Zn-Mg	As Welded	51,500	59,800	54,700	56,000	+11.1
25	75S-T bare	Zn-Mg	250° F, 24 hr.	60,000	58,200	57,700	56,100	6.5
26	75S-T bare	Zn-Mg	920° F, $\frac{1}{2}$ hr., H ₂ O, 250° F, 24 hr.	76,500	77,400	83,600	75,700	1.5
27	75S-T bare	5% Si	As Welded	44,900	45,900	47,200	43,900	2.2
28	75S-T bare	5% Si	250° F, 24 hr.	58,000	55,200	52,200	50,700	17.2
29	75S-T bare	5% Si	920° F, $\frac{1}{2}$ hr., H ₂ O, 250° F, 24 hr.	66,250	74,400	62,200	49,800	26.4

Note: All quenches were in cold water.



Figure 13—Equipment used for the loss of strength tests.

of specimen was not protected in any way and allowed corrosive action to take place at any point on the specimen where potential conditions were favorable. These two types of specimens are shown in Figure 12. Figure 13 shows the tanks and equipment used in immersing these specimens in the H_2O_2 -NaCl solutions. As can be noted, the specimens were insulated from each other by the use of wood spacers and glass rods. A typical example of the specimens corroded by the method described above is shown by Figure 14. Table I shows a loss of ultimate joint strength of the 24S-T Alclad welded specimens upon corrosion in the H_2O_2 -NaCl solution. It is to be noted that the heat numbers of the welding rod used to weld the Alclad 24S-T involved different analyses so that there has been a different rate of attack, due to solution potential differences between the weld bead and the parent metal sheet stock. Table II shows the chemical composition of the various welding rods reported on in this work.

Metallizing or spraying the weld bead of clad 24S-T after welding with 2S aluminum was found to be a means of giving additional mechanical and chemical protection to the weldment. This confirmed a German report on this practice.

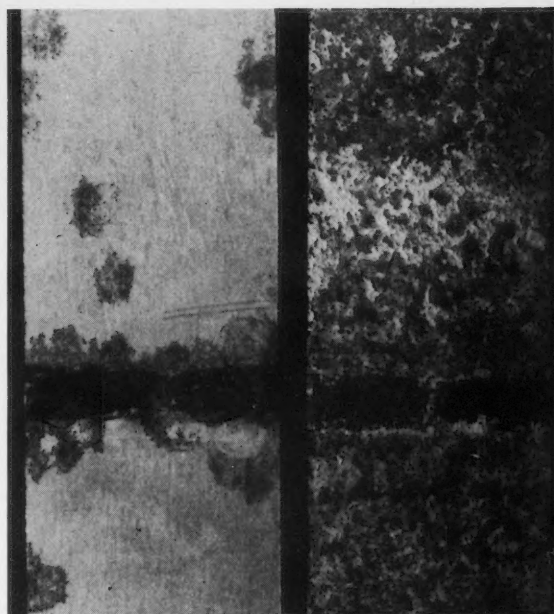
24S Outdoor Exposure

In order to correlate the accelerated laboratory corrosion results of welded 24S alloy with outdoor exposure, 7 specimens of 29 different welding combinations were placed on an outdoor rack over 2½ years ago. Figure 15 shows the rack on top of Cornell Aeronautical Laboratory located at the airport in Buffalo, New York. Prevailing winds are from the direction of two neighboring steel companies and accordingly the environment may be classed as semi-industrial. Table III shows the alloys and ultimate joint strength test data of different welding combinations upon exposure of 6, 12 and 29 months' time on this rack.

A metallographic examination was made on representative specimens after the 29 months' evaluation. Figure 16 is a photomicrograph of the cross section of the precipitated zone in welded bare 24S-T4 sheet in the as-welded condition. Intergranular corrosion attack is severe. The specimen is unetched and at 50X. It can be noted from Table III that this speci-

10 PERIODS
with Tygon

10 PERIODS
without Tygon



15 PERIODS
with Tygon

15 PERIODS
without Tygon

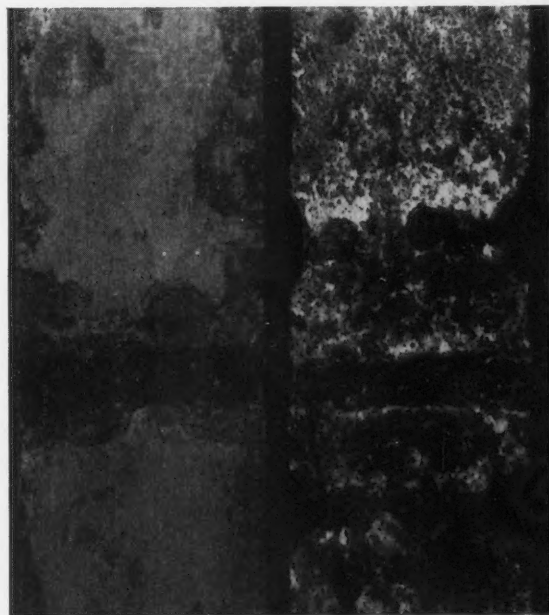


Figure 14—Representative loss of strength specimens showing the effect of Tygon paint protection and length of time of corrosion. Each period is six hours' exposure to fresh salt-peroxide solution. .064-inch, 24S-T4 Alclad, Rod Heat No. 10, corroded in H_2O_2 -NaCl solution.

men from the 12th month's test to the 29th month's test lost possibly 12 percent of its joint strength. Figure 17 shows the intergranular corrosion attack on the same specimen at the partial fusion area, which is next to the weld bead. Figure 18 is a photo-

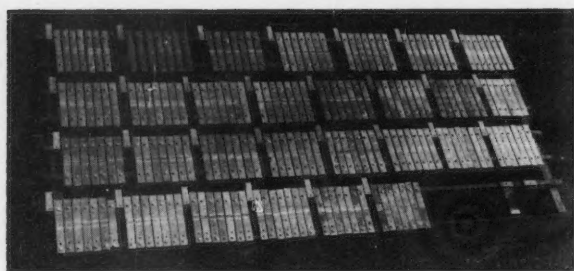


Figure 15—Outdoor exposure rack on roof of laboratory at Buffalo, N. Y.

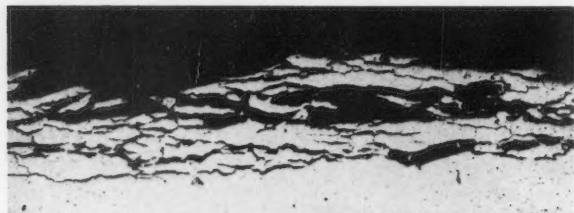


Figure 16—Transverse section of the precipitation zone of welded bare 24S-T4 sheet in the as-welded condition after 29 months in Buffalo, New York, semi-industrial atmosphere. Intergranular attack is severe. Unetched. 50X.

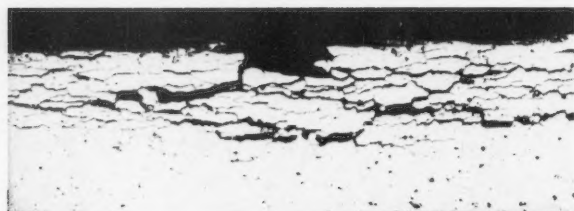


Figure 17—Transverse section of the partial fusion zone of the same specimen as in previous figure. Unetched. 50X.

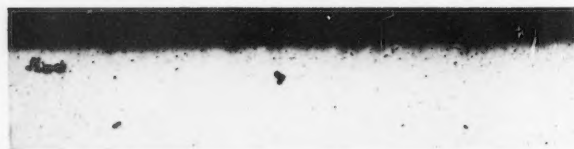


Figure 18—Transverse section of the precipitation zone of welded bare 24S-T4 sheet in the reheat-treated condition after 29 months in Buffalo, N. Y., semi-industrial atmosphere. This shows only slight pitting corrosion as compared to the severe intergranular corrosion shown in the bare specimen in the as-welded condition. Unetched. 50X.



Figure 19—Transverse section of the overheated zone of welded bare 24S-T4 sheet in the reheat-treated condition after 29 months in Buffalo, N. Y., semi-industrial atmosphere. The attack is mainly pitting in nature. Unetched. 50X.

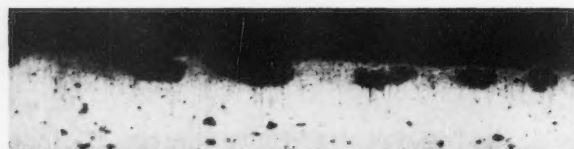


Figure 20—Transverse section of the precipitation zone of welded clad 24S-T4 sheet in the as-welded condition after 29 months in Buffalo, N. Y., semi-industrial atmosphere. This demonstrates the protection given the susceptible core by the clad coating. Unetched. 250X.

micrograph of the cross section of welded bare 24S-T4, a comparable section to that shown in Figure 16 except that the weld is in the reheat-treated condition. In comparison to the intergranular corrosion noted in the as-welded specimen, the reheat-treated specimen shows only slight surface pitting indicating that the susceptibility has been removed by proper heat treating after welding. The specimen showed no loss in strength (in fact, it was higher than any other in the same group). Figure 19 is a photomicrograph of bare 24S-T4 sheet in the reheat-treated condition taken across the overheated zone for comparison to the area shown in Figure 17. The attack is of a pitting nature. Figure 20 is a cross section view of the precipitated zone in welded clad 24S-T4 in the as-welded condition. The attack is only surface pitting and not intergranular as in the case of the bare sheet in the as-welded condition. This demonstrates the value of the cladding. Figure 21 shows that even though the specimen is clad there is an area at the clad weld bead junction which may show corrosion attack. This photomicrograph of Alclad 24S-T4 in the as-welded condition shows slight intergranular corrosion in the partial fusion area very close to the bead junction, which has been due to core diffusion through the clad. However, no significant loss in ultimate joint-strength was found upon tensile test after 29 months.

These physical and metallographic tests show close correlation with the accelerated laboratory tests, for the determination of the susceptibility to intergranular corrosion in the 24S sheet alloy upon fusion welding.

Multi-arc welded specimens prepared under similar circumstances have been set out by the National Bureau of Standards for exposure to marine atmosphere and in tidewater.

A progress report by the Bureau¹² has been written covering specimens tested in the salt spray cabinet for three months and those which were removed from the tidewater and marine atmosphere after six and twelve months of exposure. The six months' and the year exposure specimens showed that the general rate of attack for the bare, clad and reheat specimens under marine exposure was comparable to the laboratory evaluation.

Stress Corrosion Cracking Tests on 24S

The influence of stress upon the corrosion characteristics of aluminum has been well studied and reported upon by many investigators.¹³⁻¹⁷ Accelerated laboratory tests have been evaluated which produce results which can be correlated with service tests. The apparatus used for checking the stress corrosion cracking susceptibility of welded 24S sheet alloy in this laboratory is similar to that described by M. R. Hunter of RPI in his work on stress corrosion cracking in magnesium alloys.¹⁸ Figure 22 is a sketch of the method of loading the specimens. The constant bending load is applied to the weld specimens by means of weight acting through a moment arm. The load, P , necessary to produce any desired stress in

the outer fiber of the specimen is calculated from the bending equation:

$$M = \frac{SI}{c}$$

$$P = \frac{M}{l}$$

where P = load; M = bending moment; l = lever arm, distance from application of load to point for which stress is figured; S = desired stress in lb./sq. in.; I = moment of inertia of sheet action; c = half thickness of sheet.

The corrosive medium used in these stress corrosion experiments on 24S was the standard sodium chloride-hydrogen peroxide solution. Tests were carried on at room temperature. Figure 23 shows the apparatus used. Table IV shows the results of these stress corrosion cracking tests. No failures attributed to stress corrosion cracking susceptibility could be found as a result of these tests.

Failure occurred in the heat-treated specimens almost invariably at the junction between the over-heated parent metal and the cast structure. The nature of the failure was one of intergranular corrosion. Summary results of the experiments conducted indicated that the stress applied to the heat-treated specimens had no accelerating effect upon the corrosion of the welds.

In the case of the as-welded specimen, some trouble was encountered since with the standard strength salt-peroxide solution the specimens yielded plastically at the point of maximum stress, but did not break during the test. It was necessary to go to triple strength solution to produce breaking. Bending, of course, occurred at the point of maximum stress, which coincided with the precipitation or annealed zone of the weld. The yield strength in this zone is not too well defined but is naturally lower than it is in the heat-treated specimens. The probable reason for failure occurring in the triple strength corroding medium is that with bending occurring at a fixed rate, the triple strength solution merely attacks the

weld junction before bending can occur, whereas the weaker solution does not.

Other stress corrosion cracking experiments were conducted with welded 24S-T4, involving a 6 percent

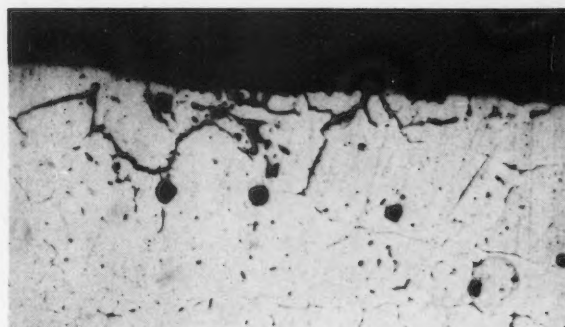
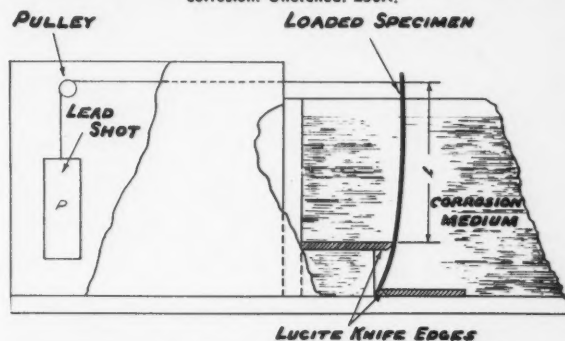


Figure 21—Transverse section of the overheated zone of welded clad 24S-T4 sheet in the as-welded condition after 29 months in Buffalo, N. Y., semi-industrial atmosphere. This shows slight intergranular corrosion. Unetched. 250X.



DIAGRAMMATIC SKETCH SHOWING METHOD OF LOADING STRESS CORROSION SPECIMENS

Figure 22—Diagrammatic sketch showing method of loading stress corrosion cracking specimens.

TABLE IV—Stress-Corrosion Cracking Tests of Welded Alclad 24S Alloy

Spec. No.	Condition	Cutting Dir.*	Applied Stress		Time Under Test		Normal Tensile Strength	Corroded Tensile Strength†	Loss Percent	Solution Strength	Remarks
			Lb./Sq. In.	Yield Strength Percent	Total Hours	Under Stress Hours	Lb./Sq. In.	Lb./Sq. In.			
1-5	As received sheet (not welded)	L	33,500	66	96	96	70,000	52,700	24.7	Triple to normal	Triple strength 1st 24 hr. only Specs. did not break.
21-25	As welded	L	28,500	80	20	Not timed	45,980	28,500	38.0	Triple	Broke at weld.
26-30	H.T. (925° F and cold H ₂ O quench)	L	28,500	70	96	96	57,700	Not tested 43,920	....	Triple to normal	Did not break. Triple str. 1st 24 hr. only.
36-40	H.T.	T	32,850	82	120	120	55,280	....	20.5	Normal	Did not break.
31-35	As welded	T	31,600	90	15½	Not timed	40,430	....	....	Normal	Bent at knife edge.
41-45	As welded	L	32,100	90	15½	Not timed	45,980	....	....	Normal	Bent at knife edge.
46-50	H.T.	T	36,300	90	72	Not timed	55,280	36,300	34.3	Normal	Broke at weld.
51-55	H.T.	L	36,600	90	72	Not timed	57,700	36,600	36.6	Normal	Broke at weld.
81-85	As welded	T	26,300	75	16	Not timed	40,430	....	....	Normal	Bent at knife edge.
76-80	As welded	L	26,800	75	16	Not timed	45,980	....	....	Normal	Bent at knife edge.
91-95	As welded	T	22,800	65	24	Not timed	40,430	....	....	Normal	Bent at knife edge.
86-90	As welded	L	23,200	65	24	Not timed	45,980	....	....	Normal	Bent at knife edge.
96-100	H.T.	L	36,600	90	72	72	57,700	48,100	16.7	Normal	Did not break.
101-105	H.T.	T	36,300	90	72	72	55,280	41,560	24.8	Normal	Did not break.
66-70	As welded	T	0	0	24	0	45,980	28,590	37.8	Normal	Unstressed.
71-75	As welded	T	0	0	24	0	40,430	23,040	43.0	Normal	Unstressed.
56-60	H.T.	L	0	0	72	0	57,700	46,060	20.2	Normal	Unstressed.
61-65	H.T.	T	0	0	72	0	55,280	35,650	35.5	Normal	Unstressed.
124-133	As welded	L	28,000	79	7	7	45,980	28,000	39.0	Triple	Broke as weld.
134-143	As welded	L	0	0	7	0	45,980	34,110	26.0	Triple	Unstressed.

* L indicates that welded strips were cut with long dimensions parallel (longitudinally) to the rolling direction.

T indicates that welded strips were cut with long dimension transverse to the rolling direction.

† Corroded T. S. is the tensile strength after the specimen was removed and pulled or, if the specimen broke in the jig, the load applied to the specimen.

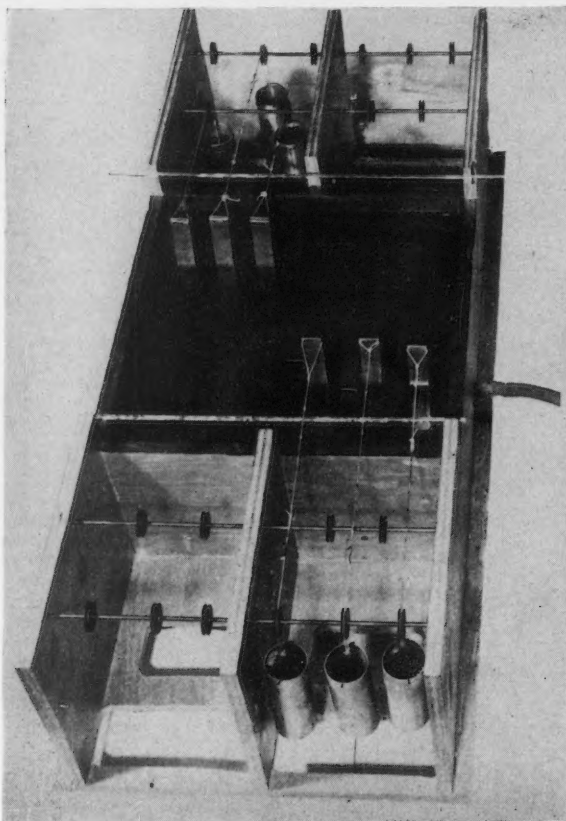


Figure 23—Stress corrosion apparatus.

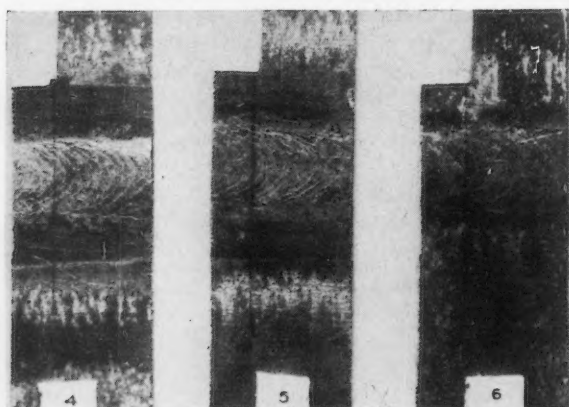


Figure 24—61S-T6 welded with 43S rod after intergranular corrosion test of salt-peroxide solution for 60 hours: Specimen 4—*as-welded*. Specimen 5—aged at 350 degrees F for eight hours. Specimen 6—solution treated 970 degrees F, cold water quenched, aged at 350 degrees F for four hours. Approximately $\frac{3}{4}$ size.

boiling salt solution medium and using a loading of 90 percent of the average yield strength determined on unexposed welded specimens. After 450 hours exposure, no failure resulted. Although this is a good exposure time for 75S alloy for susceptibility to stress corrosion cracking, it was used as another additional check on 24S alloy since some of the filler rods were zinc-magnesium-aluminum alloys. The technique of these tests is described in the 75S stress corrosion cracking portion of this paper.

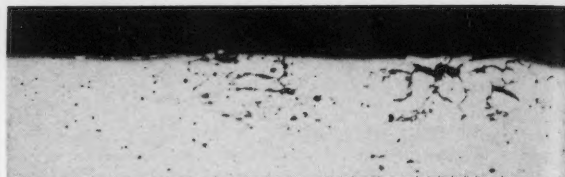


Figure 25—Transverse section of welded 61S-T6 in reheat-treated condition. Slight intergranular corrosion has occurred in the partial fusion zone. Unetched. 100X.

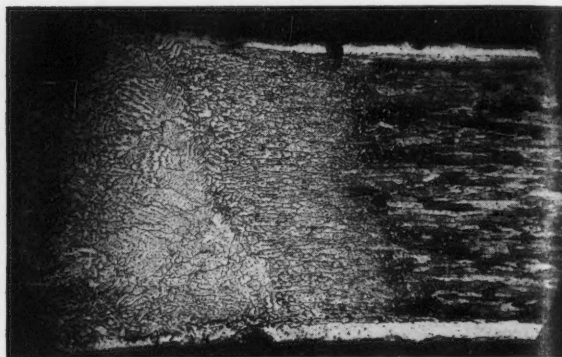


Figure 26—Transverse section of clad 75S-T6 weld in the as-welded condition showing the fusion and partial fusion zones. Keller's etch. Approximately 25X.

No reported service failures of 24S alloy from stress corrosion causes were found in the literature. Results of other investigators on the stress corrosion of 24S alloy showed no susceptibility. In light of these facts, no outdoor stress corrosion cracking tests were conducted on welded 24S.

61S Alloy

The evaluation of fusion welded Alcoa 61S sheet alloy was conducted for comparison to the 24S and 75S data. Alcoa 61S is an intermediate strength, heat-treatable aluminum alloy of the magnesium silicide class. This alloy possesses excellent resistance to corrosion in all of its tempers and is particularly adapted to fusion welding.

Intergranular Corrosion

Laboratory exposure for intergranular corrosion susceptibility was conducted in the same manner as were the experiments on 24S alloy. Loss in strength

TABLE V
Loss of Strength Due to Corrosion Attack on Welded 61S Alloy
61ST .064-Inch Thick Welded With 61S Rod

	Ultimate Strength Exposed Specimens	Ultimate Strength Unexposed Specimens	Percent Elongation Exposed Specimens	Percent Loss of Strength
As Welded.....	27,050 psi	28,100 psi	4.5	3.8
Solution Treated 970° F. $\frac{1}{2}$ hr., Cold Water (45°F.) Quenched and Aged as Follows:				
Room Temperature...	32,450 psi	35,050 psi	15.8	7.5
350° F—8 hr.....	37,400 psi	41,800 psi	4.8	10.5
350° F—24 hr.....	37,900 psi	43,400 psi	2.3	12.8
375° F—8 hr.....	37,500 psi	40,300 psi	4.3	7.0
375° F—24 hr.....	35,150 psi	39,800 psi	1.8	11.5
400° F—8 hr.....	35,700 psi	39,000 psi	2.8	8.5
400° F—24 hr.....	32,075 psi	35,500 psi	3.3	9.5

Exposure was 60 hours duration in the standard salt-peroxide solution with additional peroxide being added.

due to attack by the salt-peroxide solution is shown in Table V. In this test, exposure was 60 hours' duration with additional peroxide being added to insure continued corrosive action.

Results of this investigation showed that welded 61S-T6 sheet using 43S type filler rod had superior corrosion resistance to welded Alclad 24S-T4. Metallographic examination showed little or no attack. Figure 24 shows welded 61S-T6 alloy after exposure to the salt-peroxide solution in the three test conditions. Figure 25 is a cross section view of the slight intergranular corrosion attack in the parent sheet of welded 61S-T6 after exposure to the salt-peroxide solution. This section was the most severely attacked area on the specimen. Corrosion resistance in all conditions after welding appears to be good.

75S Alloy

The effect of welding heat on Alclad 75S-T6 sheet alloy produced similar changes in the microstructure that were noted in the Alclad 24S-T4 sheet when welded. The various zones ranging from the fusion zone of the weld bead to the partial fusion, solution and the precipitation or coalescent zone of the parent metal were noted in the microstructure. Figure 26 shows these zones in a cross-sectional view of Alclad 75S-T6 alloy welded with a zinc-magnesium-aluminum rod. With rod compositions that respond to heat treatment, it was found that strong joints could be obtained in the 75S alloy. Figure 27 shows typical joint strengths and location of failures of welded Alclad 75S-T6 upon heat treatment.

Intergranular Corrosion of Welded 75S Alloy

Specimens for corrosion testing were prepared in the same manner as those for 24S and 61S alloys. Bare 75S-T6 .064-inch thick welded specimens were corroded in the standard salt-peroxide solution in the three heat-treat conditions. Figure 28 shows the attack on bare 75S-T6 after corrosion tests. In common with the bare 24S-T4 welded specimens which were exposed to the same corrosion tests, the as-welded

and the aged specimens of 75S-T6 were severely corroded (intergranular corrosion) in that section of the sheet affected by the welding heat. In the solution treated, quenched and artificially aged specimens' intergranular corrosion was less severe and occurred only at the junction of the weld bead and the parent sheet. Figure 29 shows bare 75S-T6 in the as-welded condition after exposure to standard corrosion tests. The heavy intergranular attack shown is in the coalesced zone of the parent metal. Note that although the attack is intergranular in nature there is some appearance of pitting. This is the manner in which 75S alloy corrodes when susceptible to intergranular corrosion. Figure 30 shows bare 75S-T6 in the as-welded condition where slight corrosion at

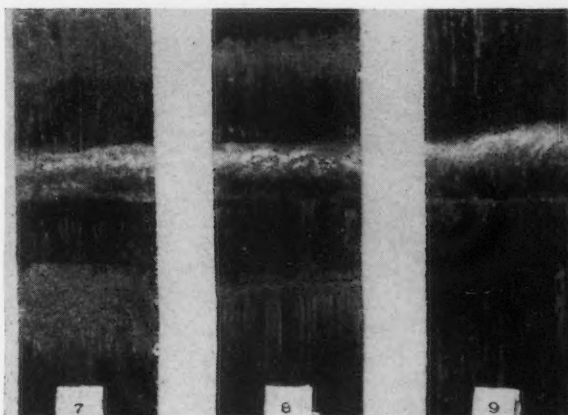


Figure 28—75S-T6 bare welded with 43S rod after intergranular corrosion test of salt-peroxide solution for six hours. 7—as-welded, 8—aged at 250 degrees F for 24 hours, 9—solution treated 920 degrees F, cold water quenched, aged at 275 degrees F for eight hours. Approximately same size.



Figure 29—Transverse section of welded bare 75S-T6 in the as-welded condition. The intergranular pitting attack has occurred in the precipitation zone after exposure to the standard six-hour NaCl-H₂O₂ solution. Unetched. 100X.

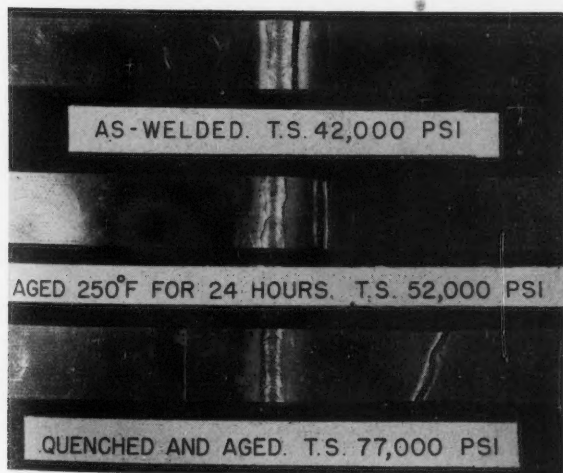


Figure 27—Typical failures of welded 75S-T6 clad upon mechanical testing.

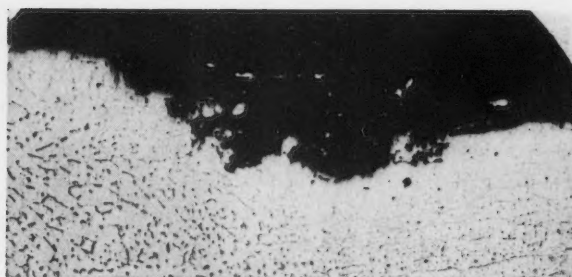


Figure 30—Transverse section of welded bare 75S-T6 in the as-welded condition. Slight intergranular corrosion has occurred at the bead-parent metal junction. Unetched. 100X. Test was in salt-peroxide solution for six hours.

the junction of the weld bead and parent metal took place.

In evaluating a group of high strength welding rod alloys for 75S welding, an accelerated corrosion test was run using clad 75S-T6 welded specimens with and without Tygon paint. The same procedure as described above for the Alclad 24S-T4 specimens in the similar type of test was used. Table VI shows the loss of ultimate joint strength upon prolonged exposure to the $\text{NaCl-H}_2\text{O}_2$ solution. It is apparent that certain filler rod alloys exhibit quite an influence on the rate of corrosion, and the study of the compositions involved indicate possible element additions for reducing the susceptibility to intergranular corrosion in high-strength aluminum alloys.

Outdoor Exposure of Welded 75S Alloy

The outdoor exposure rack shown in Figure 15 included some 75S-T6 alloy welded specimens in both bare and clad conditions. Table III shows that 75S-

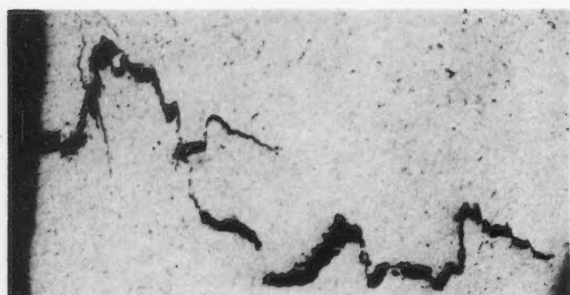


Figure 31—Crack in welded and reheated clad 75S-T6 after 29 months in Buffalo, N. Y., semi-industrial atmosphere and tensile testing. Unetched. 50X.

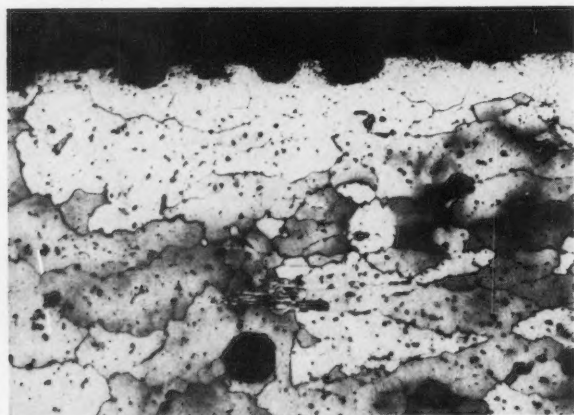


Figure 32—Transverse section of welded and reheated clad 75S-T6 showing pitting attack in the overheated zone after 29 months in Buffalo, N. Y., semi-industrial atmosphere. Keller's etch. 150X.

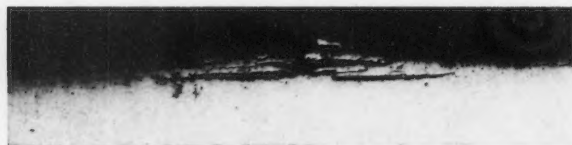


Figure 33—Transverse section of welded bare 75S-T6 in the as-welded condition after 29 months in Buffalo, N. Y., semi-industrial atmosphere. Area shown is the precipitation zone and a slight intergranular attack has occurred. Unetched. 50X.

T6 alloy and rod compositions were evaluated. It also shows the ultimate joint strength after 6, 12 and 29 months' exposure.

A metallographic examination was made on representative specimens after the 29 months' evaluation. Welded clad 75S-T6 shows good resistance to intergranular corrosion. In one specimen which was clad 75S-T6 welded with a zinc-magnesium base rod and reheated, the ultimate joint strength was low: a percentage loss of 55.7 from the original strength (specimen 20, Table III). Figure 31 shows possible explanation for this. A crack runs transverse in the weld bead adjacent to the weld bead-parent metal area. A companion specimen showed no cracks in the unpulled condition. No stress was applied intentionally to the specimen, but being fastened by both ends it is possible that some stress was imposed. The crack could be a welding crack which occurred at some phase of the welding operation.

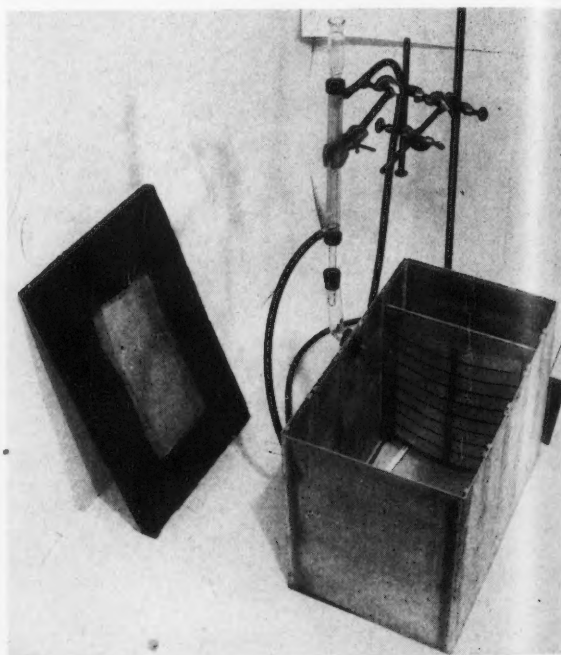


Figure 34—Boiling 6 percent NaCl solution-stress corrosion cracking apparatus.

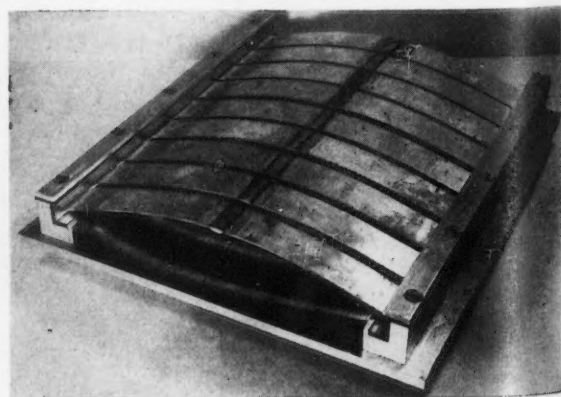


Figure 35—Specimen frame for stress corrosion cracking apparatus.

Figure 32 shows the pitting attack at the partial fusion zone in the clad 75S-T6. Diffusion of the core materials has weakened the resistance of the clad in this area.

The 29 months' atmospheric attack on bare 75S-T6 in the as-welded condition is shown in Figure 33. This was taken of the precipitation zone which showed up the poorest in as-welded bare 24S-T4. A slight intergranular attack has occurred, but it showed no effect on the ultimate joint strength.

Accelerated Stress Corrosion of Welded 75S Alloy

The method of testing for susceptibility to stress corrosion cracking was one developed by Sager, Brown and Mears of Alcoa Research and presented at the joint ASTM-AIME Symposium on Stress Corrosion Cracking (1944).¹⁰ Of methods described in the paper, the constant deflection method was selected, because the results are comparable with other means and the equipment necessary is much less expensive to fabricate and simpler to operate. Photographs of the apparatus—the tank and the frame with specimens sprung into place—are shown in Figures 34 and 35. The frames are adjustable, made of aluminum, with plate glass lined grooves to hold the specimens. The specimens contact only this glass and are electrically insulated from the frames and from each other. The grooves were set 8.6-inches apart. The corroding solution used was 6 percent boiling NaCl with a specific gravity of 1.0413 at room temperature. Distilled water was used, because tap water formed a sludge coating on the specimens due to the hardness of the water. A reflux condenser kept the boiling solution at a constant concentration. This concentration was checked daily by using a hydrometer on a cooled sample of the solution. More distilled water was added as required.

The physical properties of the combinations of sheet and welding rod were previously determined. It was decided to stress the outer fibers of the specimens for stress corrosion to 90 percent of the yield strength obtained. The necessary calculations to determine the desired length of the specimens for this stress were made using a formula found in the above mentioned paper.

The specimens were machined, with the weld centered, to a width of one inch and a length determined

by the above referenced formula. After machining, the specimens were degreased and carefully sprung into the grooves of the frame.

The specimens were subjected to the corroding solution for 400 hours minimum, considered to be sufficient to cause cracking if the sheet and rod combination was susceptible.

The calculations for bare 75S-T6 sheet welded with 75S rod using the above formula were checked using SR strain gages on specimens placed in the

TABLE VI
Loss of Ultimate Joint Strength of Welded .064-Inch 75S-T Clad
By Corrosion in H₂O-NaCl Solution

Rod Heat No.	Heat Treatment Condition	Five Periods ¹		Ten Periods		Fifteen Periods	
		Without Tygon ²	With Tygon	Without Tygon	With Tygon	Without Tygon	With Tygon
5	As Welded.....	21.6%	0.0%	32.7%	0.0%	53.7%	14.3%
2	As Welded.....	0.0	0.0	0.0	0.0	12.4	23.4
4	As Welded.....	0.0	0.0	4.5	0.0	2.7	4.6
11	As Welded.....	0.0	0.0	0.0	0.0	0.0	12.7
34	As Welded.....	0.3	12.8	9.7	14.1	10.8	11.7
14	Aged.....	0.0	0.0	0.0	0.0	0.8	23.6
19	Aged.....	4.0	1.8	0.8	12.1	4.8	13.0
5	Aged.....	13.3	18.3	17.4	5.9	27.6	15.3
12	Aged.....	14.3	16.0	19.8	19.3	20.4	29.8
21	Aged.....	4.2	0.0	7.8	19.3	21.2	4.2
21	Solution Treated and Aged ³	1.9	1.8	1.6	1.8	11.6	16.3
17	Solution Treated and Aged	4.5	0.0	5.9	0.0	4.0	9.5
3	Solution Treated and Aged	2.6	2.9	20.2	5.9	12.5	25.6
12	Solution Treated and Aged	0.0	0.0	5.3	2.4	0.0	0.0
20	Solution Treated and Aged	1.4	5.1	3.0	6.8	21.1	0.9
75S	Solution Treated and Aged	3.8	7.3	1.5	0.7	23.0	3.3

Note 1—One Period (One period equals six hours of exposure in the standard intergranular corrosion, H₂O-NaCl Solution.)

Note 2—Tygon (Specimens with Tygon paint had all surfaces covered except the weld bead.)

Note 3—Heat treatment consisted of 920° F. for one half hour, cold water quenched, and aged at 250° F. for 24 hours.



Figure 36—Transverse section of welded 75S-T6 bare in the reheat-treated condition after three hours in boiling NaCl under a stress of 90 percent of yield strength. Keller's etch, 50X.

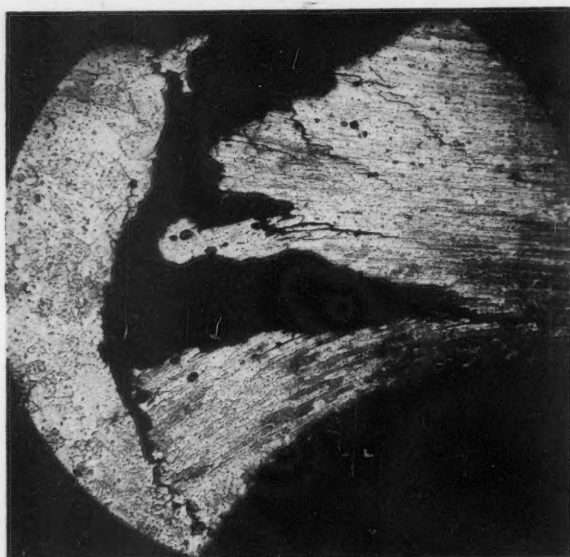


Figure 37—Transverse section of welded 75S-T6 bare in the reheat-treated condition after 17 hours in boiling 6 percent NaCl under a 90 percent stress of yield strength. Keller's etch. Approximately 28X.

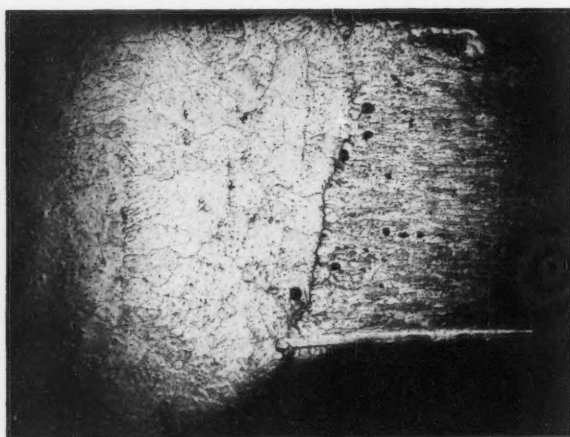


Figure 38—Transverse section of an unfailed welded 75S-T6 clad specimen in the reheat-treated condition after 52 hours' exposure to an experimental solution containing CrO_3 , NaCl and $\text{K}_2\text{Cr}_2\text{O}_7$. Crack is possibly the early stage of a stress corrosion crack. Specimen was one of three unfailed specimens of original 20. The 17 others had failed by stress corrosion cracking to the 52 hours exposure.

frame. It was found that the calculated stress and the determined stress were in close enough agreement to use the formula for the calculations.

Alclad welded specimens were also subjected to constant deflection stress corrosion. The stress, as calculated, was such that the yield of the cladding was exceeded. However, these results are included, because 75S alloy is usually used with Alclad protection and the results indicate what can be expected of the material.

In one set of experiments clad 75S-T6 .064-inch sheet welded with 75S rod was tested in the heat treat condition for stress corrosion cracking. These conditions were: "as welded," then aged for 24 hours at 250 degrees F and then solution treated, quenched and aged. The specimens withstood 560 hours exposure to the boiling

salt solution with no failure. This same combination was checked again on another project for 400 hours with no failures.

Only one failure was found, using bare 75S-T6 sheet welded with 75S rod tested in the three heat-treat conditions. In this experiment no failures occurred in the as-welded or aged conditions after 462 hours. Of seven specimens in the solution treated and aged condition, one failed due to stress corrosion cracking in three hours and the remaining six did not fail in 462 hours, at which time the test was discontinued.

In another experiment bare 75S-T6 sheet welded with an experimental rod composition of a zinc-magnesium-chromium aluminum alloy failed in less than 17 hours. In comparison, clad 75S-T6 sheet welded with this same rod withstood 450 hours' exposure.

Figures 36 and 37 show the nature of the stress corrosion crack found in the failed specimens.

Figure 38 shows a stress corrosion crack in an unfailed specimen of welded clad 75S-T6 sheet in the reheat-treated condition. This was found in a specimen which was removed from an experimental solution containing CrO_3 , NaCl and $\text{K}_2\text{Cr}_2\text{O}_7$ after 52 hours' exposure. It had not been broken, but since 17 out of 20 specimens had failed up to this time, the experiment was terminated. Micro-examinations of failures in other specimens showed that this crack represents the position and manner of failing. The crack is on the tension side of the specimen.

There are no test data available at this time on outdoor service exposure for susceptibility to stress corrosion cracking of welded 75S-T alloy.

Conclusions

From the many laboratory corrosion experiments conducted on welded 24S and 75S alloys with more or less consistent findings and from outdoor service data available at this time for correlation, some summarizing conclusions can be made:

1. Bare 24S and 75S alloys in the "as-welded" or aged conditions are very susceptible to intergranular corrosion. These alloys in the as-welded condition are definitely not recommended for any outdoor service regardless of any protection finish given them.
2. Bare 24S and 75S alloys in the reheat-treated and fully quenched and aged conditions are susceptible to intergranular corrosion to a definite degree, but not as much as in the as-welded condition. It is possible that good protective finishes may slow down the intergranular attack for outdoor exposure service for a limited period.
3. Bare 75S alloy is susceptible to stress corrosion cracking in the reheat-treated condition to some degree and contingent upon filler rod composition.
4. Welded clad 24S and 75S alloys have the best resistance to intergranular corrosion and stress corrosion cracking, especially in the reheat-treated condition.
5. When absolute freedom from corrosion is necessary and strength is secondary, the best alloy for fusion welding is still 61S.

Recommendations

From a consideration of corrosion resistance and high strength, the best high-strength aluminum alloy to fusion weld is Alclad 24S with a reheat treatment, if possible. A metallizing spray of 2S aluminum over the weld bead is also recommended. The application of a good finish with corrosion inhibiting prime coat-

ing is further insurance. This should offer sufficient protection for most applications.

For applications where requirements or corrosive conditions are not critical, unfinished clad 24 or 75S alloys with the bead sprayed with 2S alloy in the case of clad 24S, and 72S alloy in the case of clad 75S alloy, are suitable for fusion welding.

References

1. H. S. Rawdon. "Corrosion Embrittlement of Duralumin. I. Practical Aspects of the Problem." NACA T. N. 282 (April, 1928). (NACA = National Advisory Committee for Aeronautics.)
2. H. S. Rawdon. "Corrosion Embrittlement of Duralumin. II. Accelerated Corrosion Tests and the Behavior of High Strength Aluminum Alloys of Different Compositions." NACA T. N. 283 (April, 1928).
3. H. S. Rawdon. "Corrosion Embrittlement of Duralumin. III. Effect of the Previous Treatment of Sheet Material on the Susceptibility to this Type of Corrosion." NACA T. N. 284 (April, 1928).
4. H. S. Rawdon. "Corrosion Embrittlement of Duralumin. IV. The Use of Protective Coatings." NACA T. N. 285 (April, 1928).
5. H. S. Rawdon. "Corrosion Embrittlement of Duralumin. V. Results of Weather Exposure Tests." NACA T. N. 304 (February, 1929).
6. H. S. Rawdon. "Corrosion Embrittlement of Duralumin. VI. The Effect of Corrosion Accompanied by Stress on the Tensile Properties of Sheet Duralumin." NACA T. N. 304 (May, 1929).
7. E. H. Dix, Jr. "Alclad, a New Corrosion Resistant Aluminum Product." NACA T. N. 259 (August, 1927).
8. E. H. Dix, Jr. "Application of Alclad Aluminum Alloy Sheet to the Aircraft Industry." *Aviation*, 25, No. 26, 2034 (1928) Dec. 22.
9. W. Mutchler. "Corrosion of Metals Used in Aircraft." National Bureau of Standards Journal Research Paper #1316 (1940).
10. J. C. Arrowsmith and G. Murray. "The Influence of Delayed Quenching During Solution Heat Treatment on the Resistance of Duralumin to Intercrystalline Corrosion." *Sheet Metal Ind.*, 16, 1879-84 (1942), December.
11. M. R. Rivenburgh and C. W. Steward. "A Paper on Multi-arc Welding of Aluminum Alloys." *Welding Research Council of the Engineering Foundation*, IX, No. 7, 344-50 (1944), July.
12. F. M. Reinhart. "Exposure Tests of Multi-arc Welded Aluminum Alloys." Progress Report No. 1, National Bureau of Standards Report (December 28, 1950).
13. J. D. Grogan and R. V. Pleasance. "The Influence of Static Stress and Heat Treatment on the Intercrystalline Corrosion of Some Wrought Aluminum Alloys." *J. Inst. Metals*, 64, No. 1, 57 (1939).
14. L. Graf. "Zum Problem der Spannungskorrosion." *Luftwissen*, 7, 160-169 (1940).
15. E. H. Dix, Jr. "Acceleration of the Rate of Corrosion by High Constant Stresses." AIME, Tech. Pub. No. 1204 (1940).
16. R. B. Mears, R. H. Brown and E. H. Dix, Jr. "A General Theory of Stress Corrosion of Alloys." Joint ASTM-AIME Symposium on Stress Corrosion Cracking, Philadelphia, p. 329, ASTM and AIME (1944).
17. H. L. Logan and H. Hessing. "Stress Corrosion Tests on High Strength Alloy Sheet." National Bureau of Standards Journal, Research paper 1905 (1948).
18. M. A. Hunter. "Physical and Stress Corrosion Properties of Magnesium Alloy Sheet." NDRC OEM sr-1033 (October 1943).
19. G. F. Sager, R. H. Brown and R. B. Mears. "Accelerated Tests for Susceptibility to Stress Corrosion Cracking." American Society Symposium on Stress Corrosion Cracking of Metals, p. 255, ASTM and AIME (1944).

DISCUSSION

Remarks by Hugh P. Godard, Aluminum Laboratories, Ltd., P. O. Box 84, Kingston, Ontario:

When strips of sheet are bent and inserted in retaining holders for stress corrosion testing purposes we have found that extreme care must be taken in machining the strips to length and in using accurately dimensioned holders if the desired stress is to be obtained. We have found that the length tolerance must be within 0.001-inch in each case.

A Proposed Alternative Method For Measuring the Electrical Resistance Of Pipe Line Coatings*

By J. K. BALLOU, R. P. HOWELL, J. W. LILJEBERG and P. F. OFFERMANN*

Foreword

A proposed method for determining the electrical resistance of coatings on existing pipe lines was published in *Corrosion* for July, 1951 (page 245). It was presented for study by NACE Technical Practice Committee 17—Standardization for Procedures for Measuring Pipe Coating Conductance. The published method determines pipe coating resistance from average values of current and pipe-to-soil potential changes resulting from draining test currents from a buried line.

A number of engineers consider that a preferable method utilizes the so-called "attenuation" relations. These formulas have a rigorous mathematical development and when properly applied give results entirely consistent with actual conditions encountered in the field. The attenuation formulas have been found to give results differing by only a few percent from values obtained from averaging current-voltage relationships. By neglecting the effect of attenuation the averaging method shows a poor coating to have a somewhat higher resistance than its true value.

It is recommended that the NACE adopt the attenuation method described below as an acceptable alternative procedure for determining pipe coating resistance. The attenuation measurements can be made with the standard apparatus described in the previous report. This description will therefore be limited to an outline of the proposed alternative method itself.

1. Introduction

THIS METHOD of determining the electrical resistance of pipe line coatings is developed from the general relations for current and voltage in a conductor passing through a medium of finite resistivity. The following assumptions are made:

- In all cases the section of line being tested is assumed to have a uniform pipe and coating resistance (R_s and R_L in the following discussion).
- The effect of soil resistivity is neglected. Neglecting soil resistivity will have no significant effect when measurements are made on good coating in soils of low-to-moderate resistivity. With poor coating or soils of unusually high resistivity the value of coating resistance obtained by this method can be corrected as described in section 7 below.

The derivation of the equations used in this method is given in Figure 1.

2. Symbols

The following symbols will be used:

- R_s = Pipe resistance, ohms per unit length
 R_L = Coating (leakage) resistance, (ohms) (unit length)
 G_L = Coating conductance, mhos per unit length
 g = Coating Conductivity, mhos per sq ft
 i = Line current change, amperes
 e = Line voltage change, volts
 α = Attenuation constant, per unit length

$$= \sqrt{\frac{R_s}{R_L}} = \sqrt{R_s G_L}$$

R_o = Characteristic impedance

$$= \sqrt{R_s R_L} = \sqrt{\frac{R_s}{G_L}} = \alpha R_L = \frac{R_s}{\alpha}$$

$E_{o,i,x}$ = Voltage change at specific points, volts

E_T = Voltage change at end of finite line

$I_{o,i,x}$ = Current change at specific points, amperes

x = Distance between test points, unit lengths

x_1 = Length of finite line

ρ = Soil resistivity, ohm-cm

h = Distance from potential electrode to center of pipe, in.

r = Radius of pipe, in.

V_s = Voltage drop in soil between pipe surface and potential electrode.

3. General Case

Measured Currents and Voltages At Two Points Along the Line

This case is the one most frequently met in practice and corresponds to the sample given in the Committee's report. The equations assume only that the pipe and coating in the test section are uniform; they are not affected by any conditions beyond the test section. The equations are:

$$E_x = E_A \cosh \alpha x - I_A R_o \sinh \alpha x \quad (3^*)$$

$$I_x = I_A \cosh \alpha x - \frac{E_A}{R_o} \sinh \alpha x \quad (4)$$

*Submitted for publication September 10, 1951.

*All of Engineering Department, Standard Oil Company of California, Standard Oil Building, San Francisco 20, Cal.

*Numbers in parentheses correspond to equations derived in Figure 1.

$$\cosh \alpha x = \frac{1 + \left(\frac{E_x}{E_A} \right) \left(\frac{I_x}{I_A} \right)}{\left(\frac{E_x}{E_A} \right) + \left(\frac{I_x}{I_A} \right)} \quad (5)$$

4. Finite Line

This case is frequently encountered. It assumes that the line is terminated either by an insulating flange or by an electrically isolated dead end, so that a significant change in voltage to ground can occur at the end of the line where no current is flowing. An example would be a bare or coated submarine line extending out several thousands of feet from shore. The assumption does *not* apply to a line ending in a tank field or other installation which will reduce the voltage change essentially to zero while delivering a significant current to the line. The equations for a true finite line are:

$$E_A = E_T \cosh \alpha x_1$$

(6)

must hold throughout the line so that the effects of

$$I_A = \frac{E_T}{R_0} \sinh \alpha x_1 \quad (7)$$

5. Infinite Line

The formulas are:

$$E_x = E_A e^{-\alpha x} \quad (8)$$

$$I_x = I_A e^{-\alpha x} \quad (9)$$

$$I_A = \frac{E_x}{R_0} e^{\alpha x} \quad (10)$$

The infinite line involves the simplest formula, but it is seldom met with in actual practice. For this relation to be used, characteristics of the line and coating must be constant for a considerable distance beyond the section under test. Specifically, the relation:

$$\frac{E_A}{I_A} = \frac{E_x}{I_x} = R_0$$

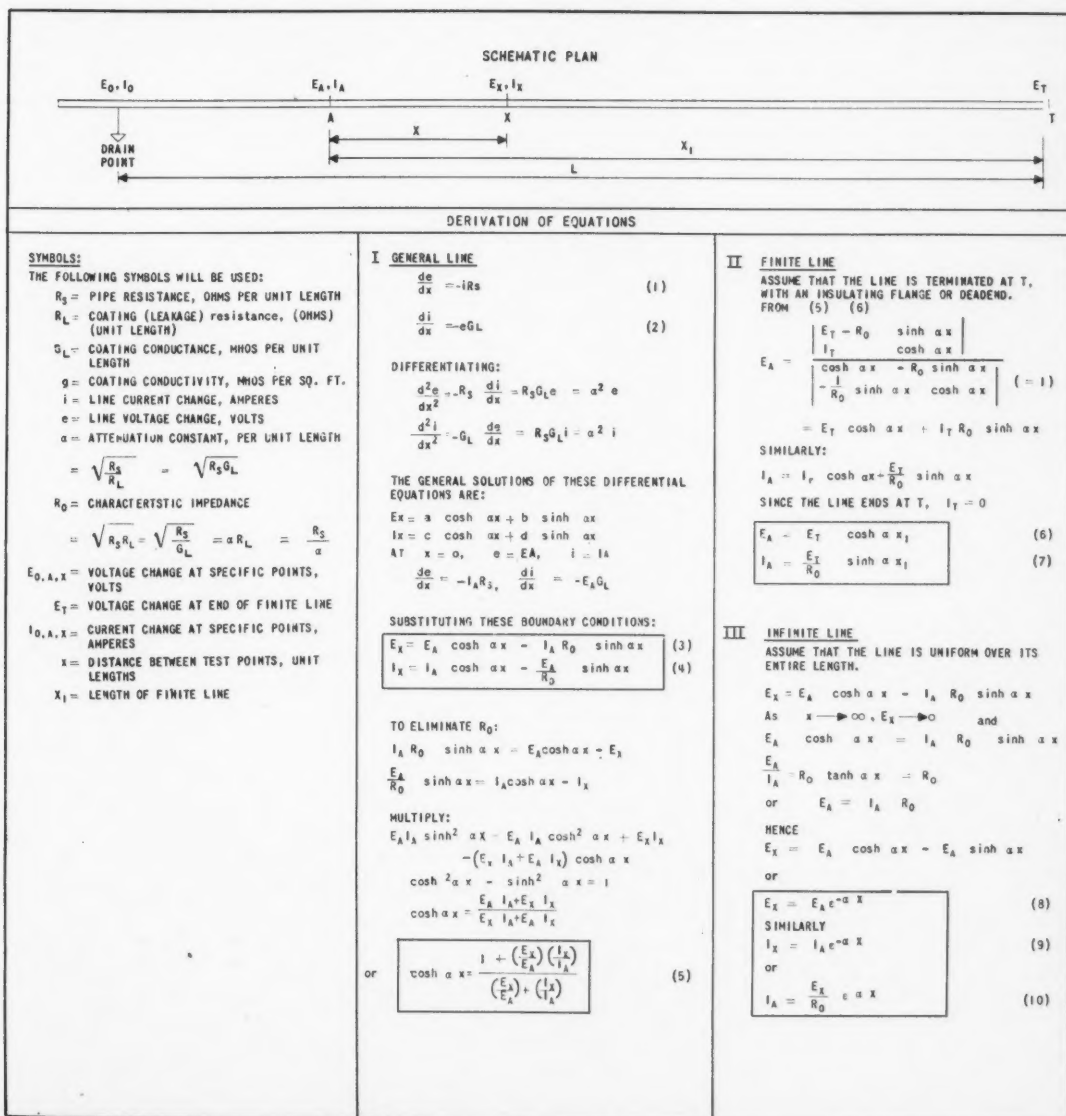


Figure 1

discontinuity are not reflected in the measurements made of the test section. It is probable that the frequent inability of engineers to reach an agreement between the attenuation method and that of the current-voltage relationships results from using the foregoing formula with the improper assumption that the section under test is part of an infinite line.

6. Determination of Coating Conductivity

Formulas (7 and (10 above may be solved by assuming values of R_L and calculating α , R_0 and the value of I_A/E_X . This value is then plotted on log-log paper and the true value of R_L obtained as indicated in Figure 2:

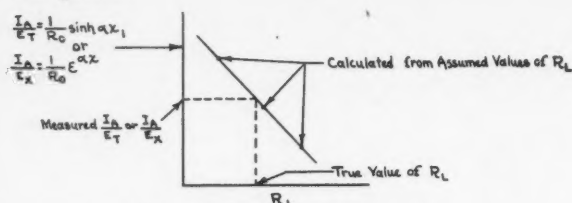


Figure 2—Graphical Solution for R_L

R_L may be obtained more directly from equations (6 or (8; however the equations containing E_A hold

only if point A is sufficiently remote from the anode. From R_L the coating conductivity or resistance per sq ft may be determined.

In the general case, the value αx is determined by substituting (measured) numerical values in equation (5; R_L , the coating resistance, is then determined from the following:

$$\alpha = \sqrt{\frac{R_s}{R_L}}$$

7. Correction for Soil Resistance

In cases of high coating conductivity or high soil resistivity, the pipe-to-soil potential changes should be corrected for the soil drop between the coating and the potential measuring electrode. This is done by subtracting the soil drop V_s as determined from the following equation from the measured pipe-to-soil potential changes.

$$V_s = \frac{(I_A - I_x)\rho}{61\pi x} \ln \frac{h}{r}$$

for x in feet

$$\text{Then } E_{A(\text{or } X)} = E_A' (\text{measured}) - V_s$$



Figure 1—Knife-line failure of a Type 347 welded drum in fuming nitric acid service.

The Mechanism of Knife-Line Attack In Welded Type 347 Stainless Steel*

By M. L. HOLZWORTH¹, F. H. BECK² and M. G. FONTANA³

Introduction

THE SUSCEPTIBILITY of austenitic stainless steels to intergranular corrosion is well known. The hypothesis most widely accepted to explain sensitization of stainless steel is the chromium impoverishment theory. This has been adequately explained by earlier investigations.^{1,2,3} Briefly, this theory postulates the formation of cubic chromium carbide, Cr_{23}C_6 , when the material is heated between 800 degrees F (427 degrees C) and 1400 degrees F (760 degrees C) for a sufficient length of time. The theoretical percentage of chromium in this carbide is 94 percent. Under normal conditions the formation of the chromium carbide occurs along grain boundaries. Thus, the chromium content of the material adjacent to the grain boundary is supposedly lowered so that this area no longer contains sufficient chromium. Hence, the chromium depleted area is susceptible to attack by certain corrosive media and intergranular corrosion occurs.

One of the preferred methods for preventing sensitization in stainless steels consists of the addition of an element that has a greater tendency than chromium to combine with carbon. This method is commonly known as stabilization. Houdremont and Schafmeister⁴ were the first to elucidate this means of preventing intergranular corrosion. The two ele-

Abstract

Recent failures because of knife-line attack occurred in welded Type 347 stainless steel drums handling fuming nitric acid. Knife-line attack is intergranular corrosion in a narrow band adjacent to the weld. This attack occurs under specific conditions. The mechanism is based on the solid solubility of niobium (columbium) in 18-8 stainless steels at high temperatures with subsequent formation of grain boundary chromium carbide during the sensitizing treatment. This type of corrosion was observed in fuming nitric acid and also in boiling 65 percent nitric acid. Experiments were conducted on regular Type 347 and Extra Low Carbon Type 347 stainless steels. The latter appeared to be less susceptible to knife-line attack.

ments most commonly used are niobium and titanium. Tantalum also possesses carbide forming properties similar to niobium.

The effect of minor constituents upon the corrosion resistance of stainless steels has been studied by various investigators.^{5,6,7,8} Of particular interest has been the effect of niobium and titanium on the corrosion resistance of the 18-8 type steels. Rosenberg and Darr⁶ stated that Nb/C and Ti/C ratios of 10 and 5, respectively, are minimum values needed to obtain almost complete immunity to intergranular corrosion. Phillips⁷ has shown the effect of grain size and free carbon content on amount of stabilizing element needed. Despite the fact that numerous investigations have been performed on the effects of these minor constituents, little work has been reported on the solid solubility at temperatures above 2000 degrees F (1093 degrees C) of niobium and

* Submitted for publication July 19, 1951.

(1) Research Associate, The Ohio State University Research Foundation, Columbus, Ohio.

(2) Assistant Research Professor, Engineering Experiment Station, The Ohio State University.

(3) Professor and Chairman, Department of Metallurgy, The Ohio State University.

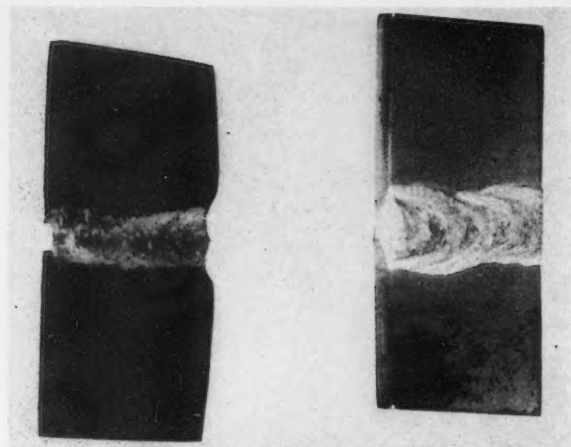


Figure 2—Steel 2. Left—Knife-line attack by boiling 65 percent nitric acid on sensitized Type 347 weld specimen. Right—No localized attack on similar specimen as-welded.

titanium in austenitic stainless steels. It has been stated that at 1200 degrees F (649 degrees C) about 0.1 percent niobium is soluble in austenite for a Type 347 stainless steel containing 0.03 percent carbon.⁸ Binder⁹ indicates that for an alloy containing about 0.70 percent niobium, all niobium carbides are in solution above approximately 2300 degrees F (1260 degrees C).

Intergranular corrosion by nitric acid of welded Type 347 stainless steel has been recently observed. This type of attack occurs in a narrow band immediately adjacent to the dendritic zone of the weld. This peculiar and somewhat unsuspected type of corrosion is designated as "knife-line attack." It differs from that of welded Type 304 stainless steel in the so-called "weld decay zone." In this case, failure occurs in a zone somewhat removed from the weld metal. Scheil¹⁰ obtained knife-line attack on various heats of Type 347 welded and subsequently sensitized at 1200 degrees F (649 degrees C) for one hour. As-welded specimens did not exhibit this phenomenon. Scheil¹¹ later postulated solubility of niobium carbide at welding temperatures, leading to chromium carbide precipitation when heated in the sensitizing range. Brown¹² reported grooving at the weld metal-parent metal junction in niobium-stabilized stainless and attributed this to carbide precipitation. Presumably, grooving is the same as knife-line attack.

Figure 1 shows the failure because of knife-line attack of a welded and stress-relieved drum of Type 347 stainless steel. The narrow band of attack adjacent to the weld zone is clearly visible. This drum was used for storage of fuming nitric acid. A large number of these drum failures occurred within a few months after filling with acid. Figure 2 shows knife-line attack in a Type 347 stainless steel chosen at random. The sample on the left side has been welded and sensitized one hour at 1200 degrees F (649 degrees C). The sample on the right was tested in the as-welded condition. These samples were given five 48-hour test periods in boiling 65 percent nitric acid.

The purpose of this investigation was to determine the mechanism of knife-line attack.

Experimental Procedure

A commercial Globar-type tube furnace was used for the heat-treatments of the samples. The temperature was controlled within ± 15 degrees F (± 8 degrees C).

Table I lists the chemical compositions of the stainless steels used in this investigation.

TABLE I
Chemical Composition of Stainless Steels

Material	Cr	Ni	C	Cb	Mn	P	S	Si
Steel 1.....	17.65	10.85	0.07	0.66	.....	.....	.....	.....
Steel 2.....	17.37	9.95	.085	.91	.....	.....	.....	.....
Steel 3.....	18.05	10.56	.087	0.72	.....	.....	.....	.....
Steel 4.....	17.15	10.36	.07	0.97	1.48	.018	.015	0.61
Steel 5.....	18.69	11.03	.03	0.38	1.40	.022	.005	0.51

Oxide formed on the specimens during heat treatment was removed by means of emery cloth. A small piece was cut from each corrosion specimen for metallographic examination. The corrosion samples were polished with number 120 emery cloth. Corrosion tests were made in fuming nitric acid and boiling 65 percent nitric acid (Huey test).

Final polishing of specimens for metallographic examination was done on a low speed wheel using a Mirocloth and Shamva powder (magnesium oxide).

Corrosion tests were carried out in 1000 ml wide mouth Erlenmeyer flasks equipped with finger-type reflux condensers. At least 125 ml of solution was maintained per square inch of specimen. The weight loss was determined after each 48-hour test period and corrosion rates were calculated from weight loss of metal.

Results and Discussion

Study of Welded Material

Welded material from a failed Type 347 drum was investigated (Steel 1 in Table I). Welding was done by the Heliarc process using argon as the protective atmosphere. After sensitizing at 1200 degrees F (649 degrees C) for two hours, Steel 1 was tested in fuming nitric acid and found susceptible to knife-line attack. For purposes of this paper and for clarity in the discussion, sensitization means heating at 1200 degrees F (649 degrees C) *whether or not* grain boundary precipitation occurs. Sensitized welded sections of Steel 2 showed knife-line attack in the Huey test. Welded Type 347 stainless steel (Steel 3), obtained from the A. O. Smith Corporation was sensitized and then examined metallographically, but not tested in acid. Metallographic examination of this alloy indicated that its microstructure was similar (grain boundary chromium carbide precipitation in the heat affected zone) to the other two which were examined and tested for knife-line attack. Corrosion data for Steels 1 and 2 with different heat treatments are summarized in Table II.

Steel 1, Table II, shows only slightly higher corrosion rates as-welded as compared to the as-received condition. The welded sample heated at a stress relieving temperature of 1650 degrees F (899 degrees C) shows about the same corrosion as the as-welded specimens. However, a sensitizing treatment at 1200 degrees F (649 degrees C) gave a much higher cor-

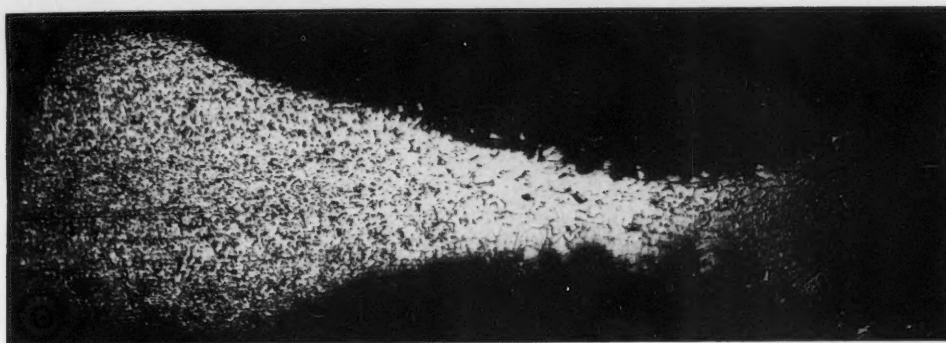


Figure 3—Knife-line attack by fuming nitric acid at 160 degrees F (71 degrees C) on sensitized Type 347 weld specimen. 30X.

rosion rate than either the as-welded or stress relieved material. This sensitized specimen developed knife-line attack and it is shown in Figure 3. It is clearly evident that attack occurs in a zone next to the dendritic zone of the weld metal. Most of the corrosion occurred in the large grained area of the specimen which is between the weld and the non-heat affected parent sheet. Figure 4 shows an enlarged view of the area in which localized attack occurred. Figure 4 clearly shows that the corrosion is intergranular and it also shows carbide precipitation at the grain boundaries. The 1650 degrees F (899 degrees C) heat treatment of welded material did not produce knife-line attack.

Welded specimens of Steel 1 with the 1200 degrees F (649 degrees C) and 1650 degrees F (899 degrees C) treatment listed in Table I were also subjected to the Strauss test. (Boiling sulfuric acid-copper sulfate solution: 47 ml H_2SO_4 and 13 gm $CuSO_4 \cdot 5H_2O$ per liter). These specimens were polished prior to testing so that the presence of intergranular attack could be detected. The specimens were removed every 24 hours, examined microscopically, and returned to fresh test solutions. The sensitized sample showed intergranular attack after an exposure of 14 days. Figure 5 shows the condition of this sample after a 14 days' test. The dark areas in the large grained region represent grains that have been removed because of intergranular corrosion. The sample heated at 1650 degrees F (899 degrees C) for one-half hour did not show any sign of intergranular attack after the same period of time.

Metallographic studies of welded samples with a variety of heat treatments indicate that the solubility of niobium is the controlling factor in knife-line attack. When this Type 347 material is cooled quite rapidly from a very high temperature, most of the

niobium stays in solution in the austenite, the niobium carbide does not precipitate or, in other words, niobium does not perform its intended function of stabilization. The alloy then behaves essentially the same as Type 304 (18-8S) stainless steel. The parent material immediately adjacent to the actual weld metal is, of course, at a high temperature during welding. This narrow zone, in which knife-line attack may develop, will be designated as the "de-stabilized" or "destabilized" zone to facilitate the discussion below.

Figure 6 shows the "junction" between stabilized and destabilized metal in Steel 1 as welded and after a sensitizing treatment at 1200 degrees F (649 degrees C). This specimen is not etched. The lower portion of Figure 6 is destabilized material and niobium carbides are not visible in this area. The carbides are visible in the upper portion of this photomicrograph which is representative of material that was not heated to a high enough temperature to dissolve the niobium carbide. This indicates that the solubility of niobium carbide is considerable for the temperatures attained during the welding process.

Figure 7 is the same as Figure 6 except that instead of a sensitizing treatment the material was heated at 1650 degrees F (899 degrees C) for one-half hour. This heat treatment did not result in the precipitation of visible niobium carbide in the destabilized zone shown in the lower portion of Figure 7.

Another specimen was prepared by depositing a weld bead on a 1/4-inch plate (Steel 3) and then sensitized by heating at 1200 degrees F (649 degrees C) for two hours. The situation pictured in Figure 6 was also observed on this specimen. Steel 3 has a niobium to carbon ratio of 8 to 3 as compared to 9 to 4 for Steel 1.

Figure 8 shows the destabilized zone in Figure 6 after etching with oxalic acid. This shows chromium carbide precipitation at the grain boundaries. This is similar in appearance to a sensitized unstabilized stainless steel (Type 304). It is apparent that under these conditions the niobium is not effective as a stabilizer. The formation of these grain boundary chromium carbides results in intergranular attack when subjected to certain corrosive media.

TABLE II
Corrosion Tests on Type 347 Stainless Steel

Material	Heat Treatment	Corrosive Media	Corrosion Rate, Mills per Year (48 Hr. Test Periods)					Avge.
			1	2	3	4	5	
Steel 1	As received sheet	Fuming nitric acid at 160° F.	130	...	...	...	...	130
Steel 1	As-welded	ditto	160	240	190	290	290	230
Steel 1	As-welded + 2 hr. at 1200° F.	ditto	730	...	...	...	...	730
Steel 1	As-welded + 1/2 hr at 1650° F.	ditto	160	270	250	290	310	250
Steel 2	As-welded	Boiling 65% nitric acid	14	12	10	13	13	13
Steel 2	As-welded + 1 hr. at 1200° F.	ditto	70	160	190	200	220	170

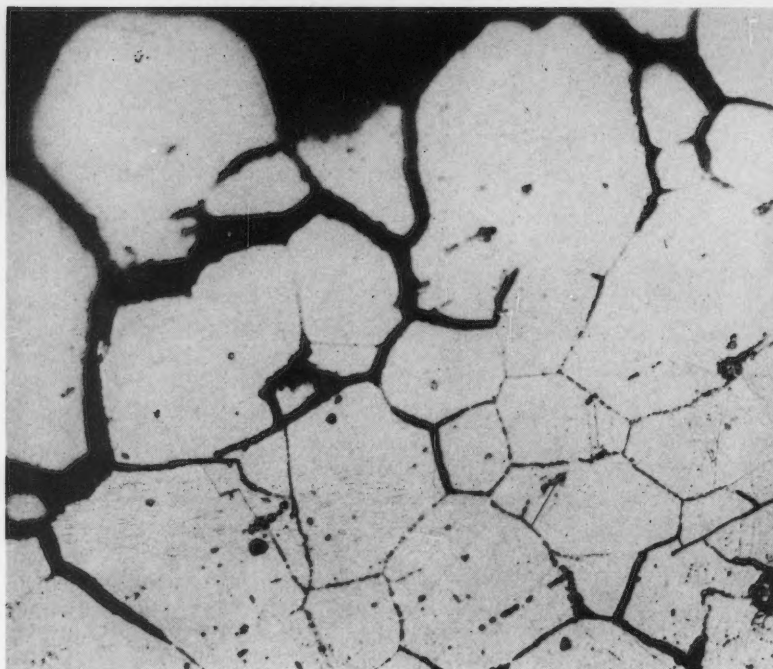


Figure 4—Enlarged view of area locally corroded in Figure 3. Electrolytic oxalic acid etch. 500X.

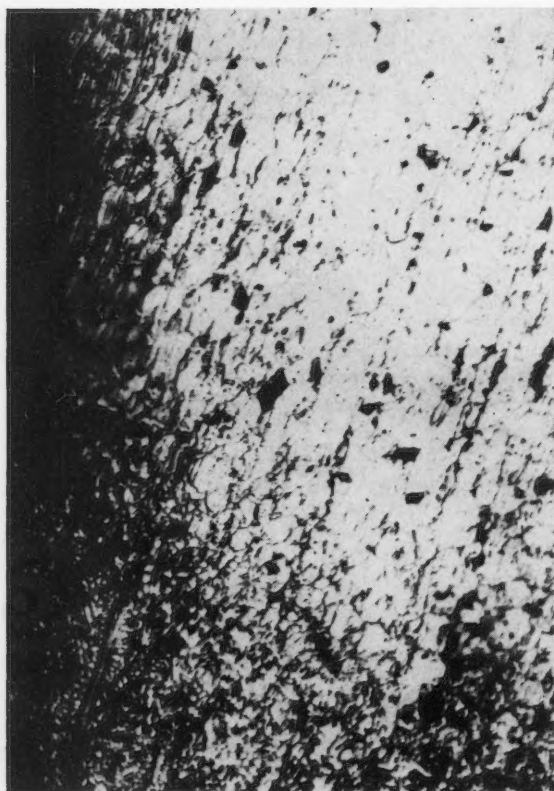


Figure 5—Steel 1 after 14 days in boiling H_2SO_4 - $CuSO_4$ solution. 30X.

Heat-Treatments Used to Simulate Welding Conditions

High temperature heat treatments were performed to determine the solubility of niobium carbide in Steel 1. Thin sections (1/16-inch) of this material, (no welds), were heated in air at 2500 degrees F (1371 degrees C), 2300 degrees F (1260 degrees C), 2100 degrees F (1149 degrees C) and 1950 degrees F (1066 degrees C) for one-half hour and water quenched. Samples were prepared in duplicate. One piece was examined in the quenched condition. The second sample was heated at 1200 degrees F (649 degrees C) for two hours. Another specimen quenched from 2500 degrees F (1371 degrees C) was heat treated at 1650 degrees F (899 degrees C) for one-half hour. All specimens were microscopically examined.

The specimen quenched from 2500 degrees F (1371 degrees C) did not exhibit niobium carbides as shown by Figure 9. A dark grain boundary zone is visible. Since unstabilized stainless steels did not show similar grain boundary regions, the evidence indicates the possibility of a solid solution enriched in niobium. This dark zone was obtained on several specimens similarly heat treated. It is felt that burning did not occur. Metallographic and corrosion data indicate the conclusion that this dark grain boundary region is not essential to chromium carbide precipitation or intergranular penetration.

Type 347 stainless steel quenched from 2500 degrees F (1371 degrees C) and sensitized at 1200 degrees F (649 degrees C) for two hours showed grain boundary precipitation. This can be seen in Figure 10. Notice the almost continuous string of chromium carbide particles located along grain boundaries. In this condition the material is very susceptible to intergranular corrosion as shown by tests in fuming nitric acid. This shows strikingly the results of solubility of niobium carbides in austenite. The steel is no longer stabilized and can be sensitized.

Figure 11 reveals a small amount of niobium carbide persisting after water quenching from 2300 degrees F (1260 degrees C) for one-half hour. The amount of carbides remaining is small, indicating substantial solubility of niobium carbide at this temperature. It is evident, therefore, that for Steel 1, complete or substantial solubility of niobium carbide occurs in the temperature range 2300 degrees F (1260 degrees C) to 2500 degrees F (1371 degrees C). Grain boundary precipitation or sensitization may occur if partial solubility of niobium carbide has taken place, since a definite amount of carbon is now available to combine with chromium. Figure 12 indicates that carbide precipitation did occur when the material quenched from 2300 degrees F (1260 degrees C) was heated at 1200 degrees F (649 degrees C). The pre-

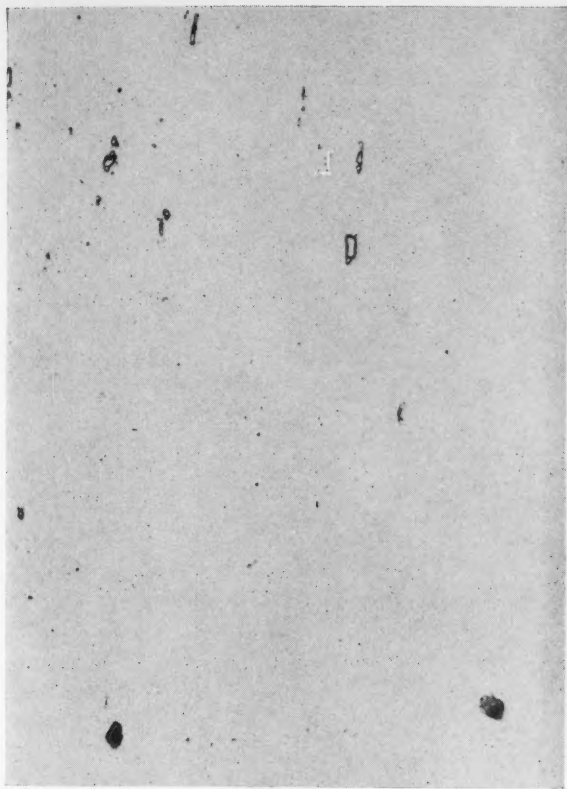


Figure 6—Stabilized and destabilized zone of steel as-welded and sensitized. Unetched. 500X.

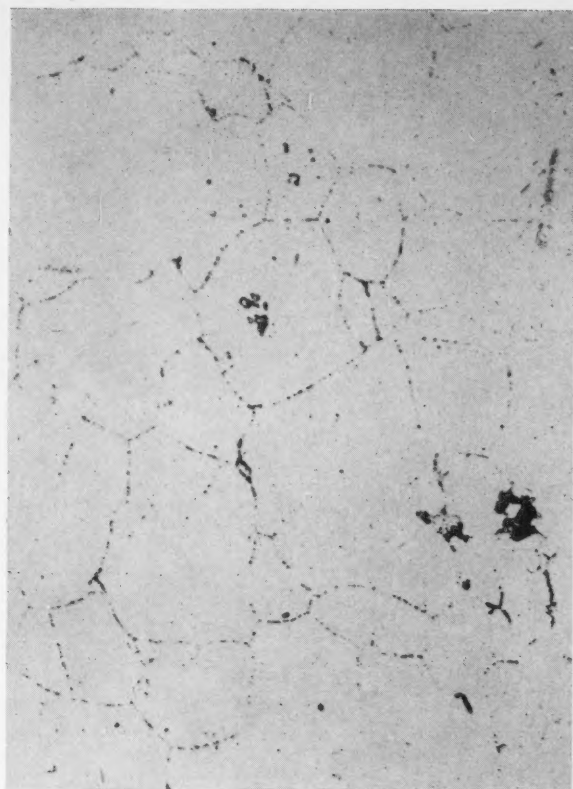


Figure 8—Destabilized zone of Figure 6. Electrolytic oxalic acid etch. 500X.



Figure 7—Same as Figure 6 except heated at 1650 degrees F (898 degrees C) for one-half hour instead of sensitizing. Unetched. 500X.

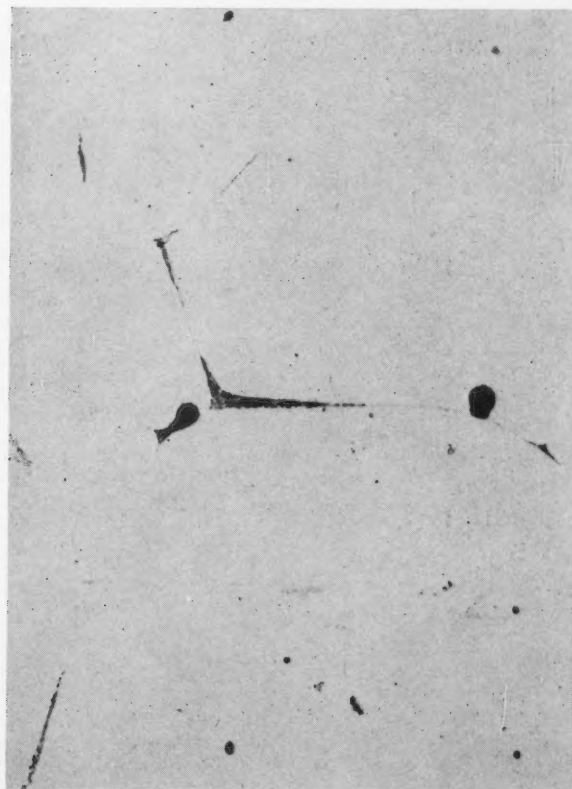


Figure 9—Steel heated at 2500 degrees F for one-half hour and water quenched. Electrolytic oxalic acid etch. 500X.

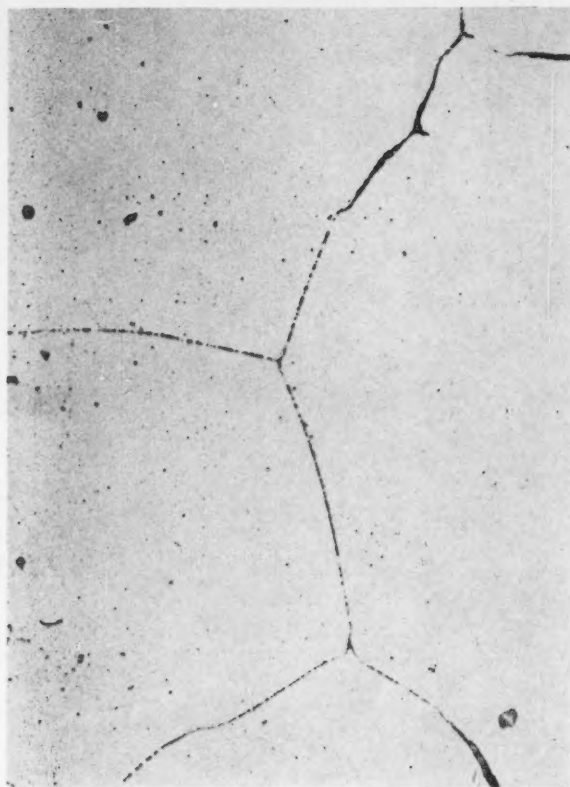


Figure 10—Same as Figure 9 except sensitized. Electrolytic acid etc. 500X.

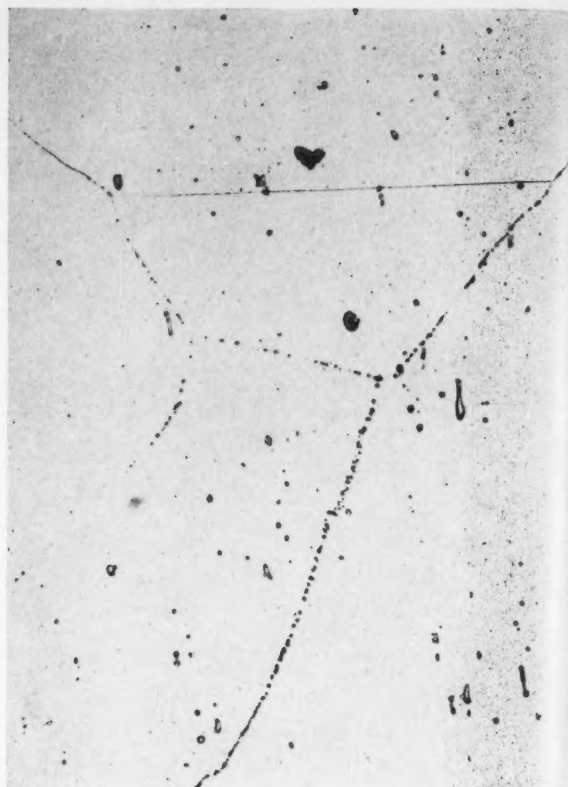


Figure 12—Same as Figure 11 except sensitized. Electrolytic oxalic acid etch. 500X.

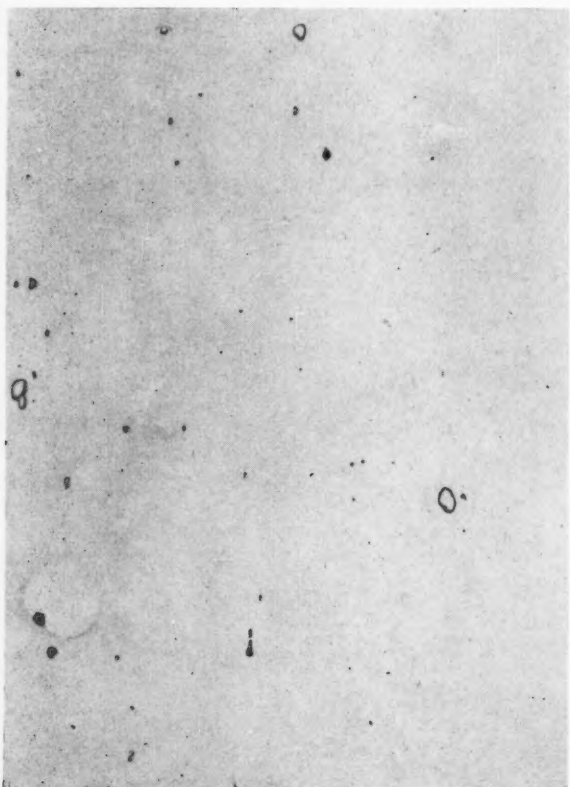


Figure 11—Steel 1 heated at 2300 degrees F for one-half hour and water quenched. Unetched. 500X.

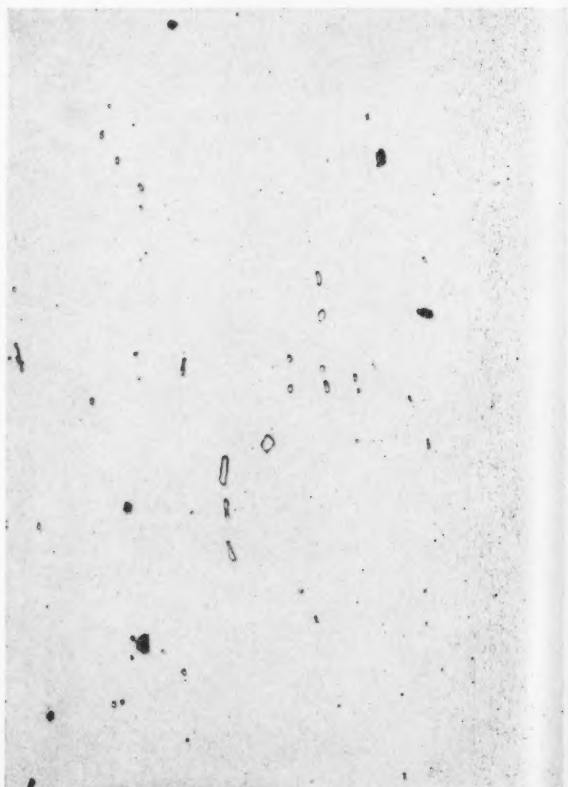


Figure 13—Steel 1 heated at 2100 degrees F for one-half hour and water quenched. Unetched. 500X.

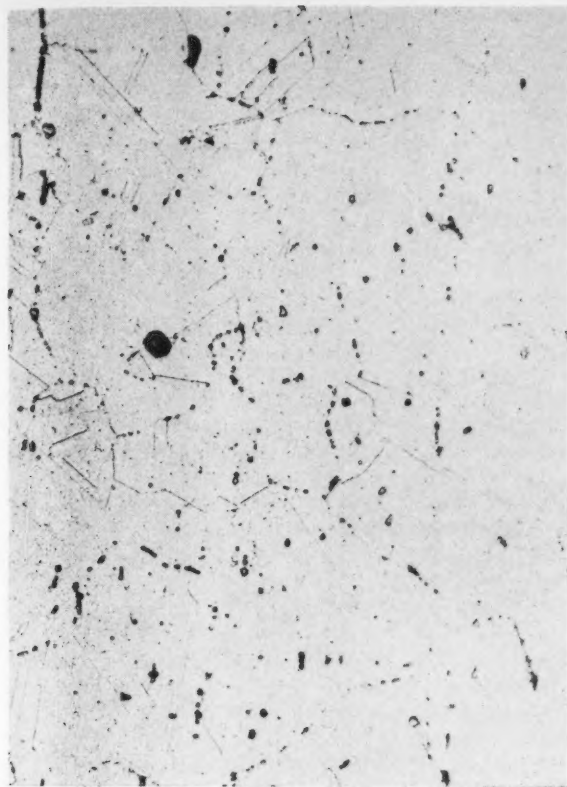


Figure 14—Steel 1 water quenched from 2150 degrees F and sensitized. Electrolytic oxalic acid etch. 500X.

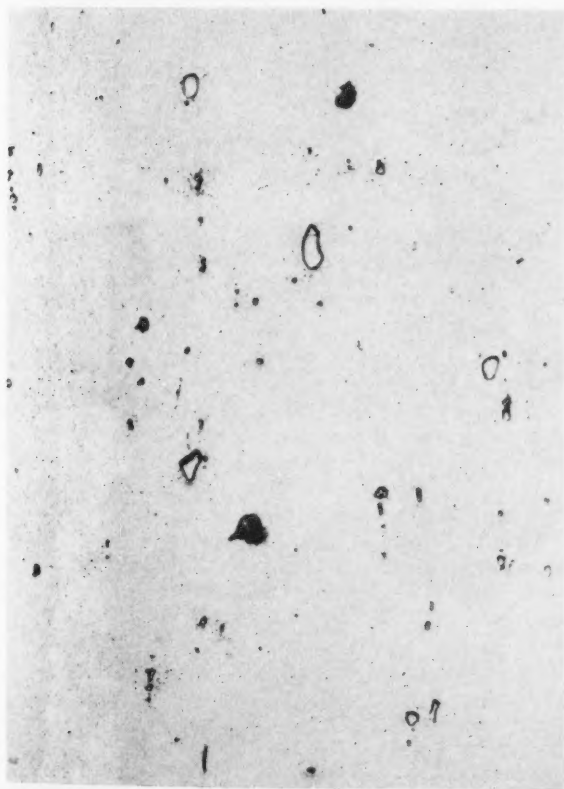


Figure 15—Steel 1 water quenched from 1950 degrees F. Unetched. 500X.



Figure 16—Steel 1 water quenched from 1950 degrees F and heated for two hours at 1200 degrees F. Electrolytic oxalic acid etch. 500X.

carbide does not appear as continuous as that shown by the specimen quenched from 2500 degrees F (1371 degrees C) and given a similar treatment at 1200 degrees F (Figure 10). Boiling 65 percent nitric acid corrosion tests show that the degree of intergranular attack is less for the specimen heat treated at the lower temperature and then followed by a sensitizing treatment.

The solubility of niobium carbide was considerably less for specimens quenched from 2100 degrees F (1149 degrees C). The distribution of carbides for this case is illustrated by Figure 13. Some carbide precipitation or partial sensitization was obtained on a sample water quenched from 2150 degrees F (1176 degrees C) and subsequently heated at 1200 degrees F (649 degrees C), (Figure 14). Corrosion data were not obtained for the material in this condition, but intergranular attack should not be seriously encountered because of lack of a continuous carbide network.

The distribution of niobium carbide particles found in Type 347 stainless steel quenched from 1950 degrees F (1066 degrees C) is illustrated in Figure 15. Figure 16 shows the same specimen after a two-hour heat treatment at 1200 degrees F (649 degrees C). The concentration of niobium carbide particles is greatest in the sample quenched from 1950 degrees F (1066 degrees C). After treatment in the sensitization range, no grain boundary precipitation occurred. This is in agreement with data that show no trace of intergranular attack when Type 347 stainless steel

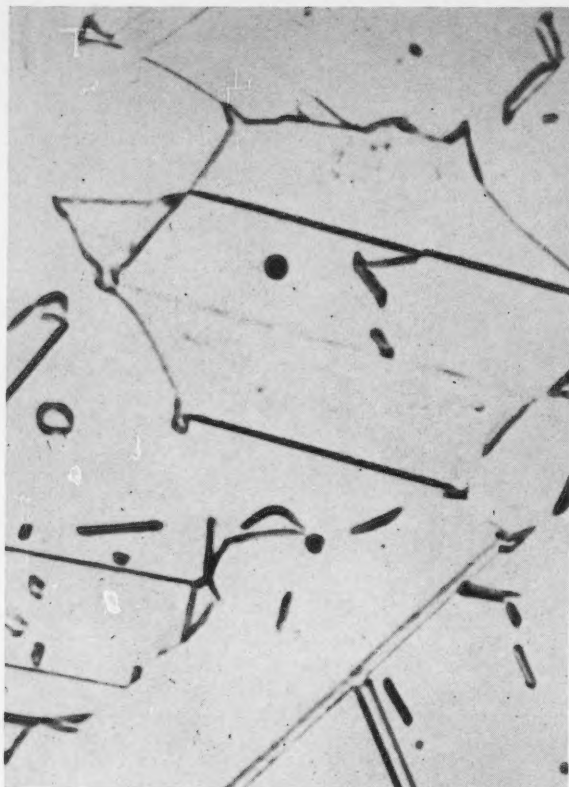


Figure 17—Steel 5. (347 ELC.) Water quenched from 2500 degrees F. Electrolytic acid etch. 500X.



Figure 18—Same as figure 17 except sensitized. Electrolytic oxalic acid etch. 500X.

is quenched from approximately 1950 degrees-2000 degrees F and sensitized.

The heat-treatments performed were in the temperature range attained during the welding operation. The results show the solubility of niobium carbides at high temperatures. A temperature between 2300 degrees F and 2500 degrees F is required to put all the niobium carbides into solution. If a material has been heated at a temperature at which total or almost complete solubility of carbides has occurred, followed by a treatment in the chromium carbide precipitation temperature range, the carbon is now free to combine with either chromium or niobium and since chromium carbide is the more stable phase at the sensitizing temperature used in this investigation, grain boundary chromium carbide precipitation takes place which then enables intergranular attack to occur. High temperature treatments produced the same results that were obtained from the welded samples. Solubility of niobium carbide was observed, and this effective loss of stabilizing element promotes intergranular corrosion and leads to knife-line attack in welded sections.

Investigation of an extra low carbon Type 347 stainless alloy (Steel 5) was made. A sample water quenched from 2500 degrees F (1371 degrees C) revealed the presence of a large amount of delta ferrite. The duplex structure consisting of austenite and high temperature ferrite is shown in Figure 17. Subsequent reheating of the sample quenched from 2500 degrees F (1371 degrees C) at 1200 degrees F (649 degrees C) for two hours did not produce the grain boundary carbide particles that were found in the regular Type 347 alloy. A darker etching constituent is noticed in the sample heat treated at 1200 degrees F (649 degrees C) Figure 18. The possibility of sigma formation must be considered in this alloy. A comparison of the corrosion rates obtained for regular and extra low carbon Type 347 stainless steel is presented in Table III.

TABLE III
Corrosion of Type 347 Stainless Steel in Fuming Nitric Acid at 160° F.

Material	Heat Treatment	Corrosion Rate Mils per Year (48 Hour Test Periods)			
		1	2	3	4
Steel 1.....	2500° F, 1/4 hr. W.Q. + 1200° F, 2 hrs. ditto	185	325	870	Dissolved
Steel 5 (ELC.)		540	390	350	270

Steel 1 completely disintegrated during the fourth 48-hour test period. The corrosion data indicate intergranular corrosion of the regular Type 347 stainless material and chiefly uniform corrosion of the extra low carbon alloy. It thus appears that the extra low carbon material is not prone to formation of detrimental grain boundary carbide particles, but might be subject to sigma formation.

Corrosion of Type 347 Stainless Steels Given Various Heat Treatments

Regular and extra low carbon Type 347 samples were heat treated and tested in boiling 65 percent

TABLE IV
Heat Treatment of Type 347 Stainless Steels

Spec.	Material	Heat Treatment
F-1	Steel 4 (Type 347)	2400° F, 1/2 hour W.Q.
F-2	ditto	1950° F, 1/2 hour W.Q.
F-3	ditto	1750° F, 1/2 hour W.Q.
F-4	ditto	2400° F, 1/2 hr. W.Q. + 1200° F, 2 hrs.
F-5	ditto	1950° F, 1/2 hr. W.Q. + 1200° F, 2 hrs.
F-6	ditto	1750° F, 1/2 hr. W.Q. + 1200° F, 2 hrs.
1	Steel 5 (Type 347 ELC)	2400° F, 1/2 hour W.Q.
2	ditto	1950° F, 1/2 hour W.Q.
3	ditto	1750° F, 1/2 hour W.Q.
4	ditto	2400° F, 1/2 hr. W.Q. + 1200° F, 2 hrs.
5	ditto	1950° F, 1/2 hr. W.Q. + 1200° F, 2 hrs.
6	ditto	1750° F, 1/2 hr. W.Q. + 1200° F, 2 hrs.

nitric acid. Heat treatment data for Steels 4 and 5 are given in Table IV and corrosion data in Table V.

Quenched samples of both regular and extra low carbon niobium stabilized alloys gave low corrosion rates. The sensitized samples of the regular Type 347 material gave higher corrosion rates. The average corrosion rates increased as the quenching temperature increased. The corrosion data indicate that sample F-4 (quenched from 2400 degrees F (1315 degrees C) and sensitized) was very susceptible to intergranular attack. Corrosion rates of the extra low carbon material indicated that this alloy was only slightly, if at all, susceptible to intergranular attack.

From the practical standpoint, the authors wish to emphasize that knife-line attack may not occur under all conditions. In fact, particular combinations of welding, heat treatment and corrosive media are required for this type of corrosion. Time-temperature relationships are important. Many corrosive media do not show selective intergranular attack. It is well to keep in mind, however, the possibility of knife-line attack when considering the design, fabrication and use of these stabilized alloys. Premature failure may be avoided.

Summary

Knife-line attack occurs only under specific conditions. The mechanism is based on the effect of temperature on the solid solubility of niobium and niobium carbide and on the grain boundary precipitation of chromium carbide. Niobium is dissolved at very high temperatures and remains in solution when cooled at a fairly rapid rate. Subsequent heating in the sensitization range promotes grain boundary chromium carbide precipitation and thus knife-line attack can occur. Knife-line attack was observed on Type 347 stainless steels in fuming nitric acid and in boiling 65 percent nitric acid. Extra Low Carbon Type 347 appears to be practically immune to knife-line attack based on the tests made in this investigation. Substantial and practically complete solubility of niobium was observed in the temperature range 2300 degrees F (1260 degrees C)-2500 degrees F (1371 degrees C) for regular Type 347 stainless steel.

TABLE V
Corrosion of Heat Treated Specimens of Type 347 Stainless Steel by Boiling 65% Nitric Acid

Specimen No.	Corrosion Rate, Mils per Year (48 Hour Test Periods)					
	1	2	3	4	5	Average
F-1.....	7	13	10	10	9	10
F-2.....	40	16	11	13	12	19
F-3.....	20	11	9	11	12	13
F-4.....	190	290	320	410	350	330
F-5.....	30	30	30	40	40	34
F-6.....	24	20	20	30	20	23
1.....	4	6	6	6	6	6
2.....	7	5	5	4	6	5
3.....	7	5	5	5	5	5
4.....	7	9	14	17	20	14
5.....	9	11	22	37	42	24
6.....	7	6	8	11	14	9

Acknowledgment

This investigation was made under Contract No. AF 33 (038)-10389 between the Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio, and The Ohio State University Research Foundation. The interest and support of the United States Air Force is gratefully acknowledged.

References

1. E. C. Bain, R. H. Aborn and J. J. B. Rutherford. "Nature and Prevention of Intergranular Corrosion of Austenitic Stainless Steels." *Transactions, American Society for Steel Treating*, **21**, 481 (1933).
2. R. H. Aborn and E. C. Bain. "Nature of Ni-Cr Rustless Steels." *Transactions, American Society for Steel Treating*, **18**, 837 (1930).
3. B. Strauss, B. H. Schottky and J. Hinnüber. "Carbide Precipitation by the Annealing of Non-Magnetic Stainless Steel." *Anorg. Allgem. Chemie*, **188**, (1930).
4. E. Houdremont, and P. Schafmeister. "Prevention of Intergranular Corrosion in Steels with 18% Chromium and 8% Nickel." *Archiv für das Eisenhüttenwesen*, **7**, 187 (1933-1934).
5. F. M. Becket and R. Franks. "Effects of Columbium in Chromium Nickel Steels." *Trans. Am. Inst. of Mining Met. Eng.*, **113**, 143 (1934).
6. S. J. Rosenberg and J. H. Darr. "Stabilization of Austenitic Stainless Steel." *Trans. Am. Soc. Metals*, **41**, (1949) 1261-1300.
7. F. J. Phillips. "Quantitative Evaluation of Intergranular Corrosion of 18-8 Ti." *Trans. Am. Soc. Met.*, **39**, (1947) 891-905.
8. W. O. Binder, C. Brown and R. Franks. "Resistance to Sensitization of Austenitic Chromium-Nickel Steels of 0.03% Max. Carbon Content." *Trans. Am. Soc. Metals*, **41**, (1949) 1301-1370.
9. W. O. Binder. "Some Notes on the Structure and Impact Resistance of Columbium-bearing 18-8 Steels After Exposure to Elevated Temperatures." *Am. Soc. Test. Mat. Preprint* (1950) 44.
10. M. A. Scheil, General Discussion, Symposium on Tests for Stainless Steels, Special Technical Publication No. 93, American Society for Testing Materials (1950) p 228.
11. M. A. Scheil. "Conservation of Columbium." *Met. Prog.*, **32**, 699. (1950) Nov.
12. M. H. Brown, General Discussion, Symposium on Tests for Stainless Steels, Special Technical Publication No. 93, American Society for Testing Materials (1950), p. 224.

The Literature on Corrosion*

By IVY M. PARKER*

Introduction

CORROSION is defined in the Corrosion Handbook¹ as destruction of a metal by chemical or electrochemical reaction with its environment. The literature on corrosion includes the reactions of metals and metal substitutes with their environments, methods of protection, properties of protective materials and service of materials and equipment in the various industries.

Sir Humphrey Davy, in the early part of the nineteenth century, began using zinc to protect copper sheathing in sea water. Dr. W. R. Whitney² proposed the electrochemical theory of corrosion in 1903. A large amount of work has been done and published in the half century since that date. Faraday has been credited with saying that the success of a scientific worker is compounded in three words—Work, Finish, Publish. A large number of scientists and engineers have followed this motto.

Attention is focused on corrosion because it is a prime cost factor to industry. It is estimated³ that corrosion costs industry some five and one-half billion dollars per year. Of this amount, it is estimated that some 20 percent can be saved by research and proper understanding of existing knowledge.

Technical Societies Contributing to Corrosion Literature

Several technical societies in this country and abroad include corrosion as one of their specific fields of interest. In England, the Faraday Society, Iron and Steel Institute and British Non-Ferrous Metals Research Association, among others, have contributed a great deal to literature on corrosion. In France, the Corrosie Commissie of CIMO has emphasized the practical side of this field. In the United States, the American Society for Testing Materials has committees reporting on the behavior of metals in atmosphere and water as well as methods of testing, specifications, etc. The Electrochemical Society has an active section on corrosion and is adding to the fundamental knowledge. The American Chemical Society has sponsored two symposia on water corrosion. The American Water Works Association, the American Gas Association, the American Petroleum Institute, American Society of Mechanical Engineers, American Society of Electrical Engineers and American Association of Railroads, among others, devote time in their technical committees and space in their publications to corrosion. The American Society for Metals stresses proper choice of materials and recognizes corrosion

Abstract

The increasing economic importance of corrosion has resulted in more attention being devoted to its causes and to means whereby it may be mitigated. Several technical societies at home and abroad have corrosion as a specific field of interest, and the National Association of Corrosion Engineers devotes its attention to it exclusively.

Corrosion literature is being published in magazines ranging from the smallest trade magazine to the most learned technical journal. A survey of 3300 abstracts of corrosion technical literature published in 1946-47 showed 542 source publications. The American Coordinating Committee on Corrosion concluded the literature on corrosion could not be sectionized because it cut across many fields.

NACE, not wishing to duplicate work already done, secured permission of established abstracting agencies to collect, classify and publish abstracts. The need for a filing system index to coordinate corrosion literature in a manner covering any field of interest and with provisions for expansion became evident with the start of the abstract program.

The NACE Abstract Committee developed a system and keyed it to a punch card to make semi-mechanical sorting possible. Random number codes are used in the system, among others, and the card finally developed includes provision for coding topics, authors, publications, and year of publication, besides leaving a substantial number of unassigned holes for use in supplementary indexing.

as an important part of its field. The National Association of Corrosion Engineers and its publications are devoted entirely to corrosion and related subjects. The Inter-Society Corrosion Committee of NACE has absorbed the duties of the former American Coordinating Committee on Corrosion and coordinates the work on corrosion done by the various associations.

Current Corrosion Literature

Because of the economic necessity for solution of industrial problems, the fight against corrosion was formerly, and to some extent still is, an art rather than a science. Until recent years there has been no specific training available to students. An individual through interest or necessity undertakes the problem and on the basis of his individual background and experience develops a solution. A large number of these solutions find their way into the industrial trade journals. At the same time, interested scientists and societies have been approaching some of the problems from a fundamental viewpoint and their findings go into the highly technical journals of almost every branch of fundamental science. Thus, corrosion literature is spread from the smallest trade magazine to the most learned technical journal.

A survey of the source of some 3300 abstracts of articles on corrosion published in 1946-1947 showed 542 different publications. To locate all of these articles in the regular abstract journals would have required searching through nearly all sections. The American Coordinating Committee on Corrosion, recognizing this wide distribution as a handicap to

*Presented to The Metals Section of the Special Libraries Association at World Metallurgical Congress, Detroit, Mich., October 15-19, 1951.
* Plantation Pipe Line Co., Bremen, Ga. Editor, Corrosion, official publication National Association of Corrosion Engineers, Houston, Texas.

workers, canvassed some of the comprehensive abstract journals to determine if corrosion abstracts could be sectionized. This appeared to be impractical because corrosion cuts across many fields. The abstract section of *Corrosion*, official publication of National Association of Corrosion Engineers, appeared a logical place to collect abstracts on corrosion. Because neither ACCC nor NACE wished to duplicate work that had already been done, those companies which publish library bulletins and the publishers of abstract journals were asked to contribute their abstracts dealing with corrosion and related subjects to the common pool. NACE adopted a program to make them easily accessible to workers in corrosion. In this program, the majority of the abstracts are printed currently in *Corrosion*. Periodically they are combined with abstracts which were currently missed and are printed in biennial publications for ready reference; and recently they are being reproduced on punch cards so that cross-indexing and semimechanical sorting will greatly improve their usage.

Filing System Index for Corrosion Abstracts

The need for a systematic filing system index to co-ordinate corrosion literature on a sufficiently broad basis to cover all aspects of any field of interest and permit expansion in any direction became evident when NACE started its abstract program. The Abstract Subcommittee* of NACE has developed a system which to a large extent fulfills the above need. It is directed toward the engineer seeking to solve a problem.

For this purpose corrosion literature has been divided into eight main groups: General, Testing, Characteristic Corrosion Phenomena, Corrosive Environments, Preventive Measures, Materials of Construction, Equipment and Industries. The first three sections—General, Testing, and Characteristic Corrosion Phenomena—give background material for analyzing problems, and the last five groups give performance information.

Each main group has been subdivided, some subjects having received more attention than others. All categories are capable of further expansion.

The complete filing system index is presented as a part of the Index to Corrosion Technical Material, 1951 in the December, 1951, issue of *Corrosion*. An alphabetical index has been provided to aid in coding, filing and searching. Both are incorporated in NACE publication 51-6.^{3a}

Punch Card System

The current interest in punch card filing of information led NACE to explore its possibilities for handling corrosion abstracts. Both mechanical and semimechanical methods were considered. A semimechanical method was selected because: 1) abstracts can be printed directly on the card, 2) non-skilled personnel can punch and search cards, and 3) inexpensive equipment is required for searching.

The punch cards have two prime virtues for classifying information: 1) A single card may be cross-

referenced a number of times, thus eliminating cross reference cards; 2) the cards may be filed in random order so that a given item cannot be lost.

The NACE filing system index was developed with this use in mind. A 5 by 8-inch card with a double row of holes around its perimeter has been selected. See Figure 1. The top outside row is used for subject index, the inside right hand row for primary classification, the inside bottom row for journal classification and reference date, and both rows on the left hand side for authors. The remaining fifty percent of the holes is available for additional coding.

Various factors were considered in setting up the codes. The random number system was chosen for the subject index, direct code for main or primary classification, SF-7-4-2-1-0 for journal and date, and a modification of the OEICB⁴ system is used for author code. Where there are more than two authors a special hole marked MA for multiple author is used.

The random number coding will be discussed in greater detail below. It was chosen because it permits the coding of the greatest number of subjects on one card and provides fewer unwanted cards on sorting than the other systems.

The direct code is used for main classifications because there are only eight of these.

The SF-7-4-2-1-0 code is used for journals, the first section representing tens and second section units. This provides 99 numbers. The journal code has been developed on the basis of the number of articles on corrosion in specific publications and 99 numbers. The journals represented in Bibliographic Survey of Corrosion—1946-1947 were listed according to the number of articles published on corrosion. On the basis of this listing, journals have been assigned code numbers from 1-99, leaving 28 numbers for future assignment. Those journals or magazines which published less than 12 articles have been given codes according to an alphabetical listing. For example, code No. 18 is used for all journals with names beginning with the letter "C" (Except: 19—Chemical Age; 20—Chemical Engineering and 21—Combustion). If the journal is published by a society, it is carried under the society's name and the society's name is listed alphabetically. Numbers 22 and 23 are left open for future expansion of "C" names.

The SF 7-4-2-1-0 code is adequate for dates and can be punched without reference to codes. As in journals, the first section codes tens and second section codes units (See Figure 1). This code applies only to twentieth century. For example, 1951 is punched five in tens section and one in units section.

The OEICB⁴ system for coding authors was modified to be made applicable to coding first and third letters in author's name which was shown by ASM-SLA committee⁵ to be more selective than first and second letter.

As mentioned earlier, some 50 percent of the holes on the card have not been assigned codes. These unassigned portions are set up so that they may be coded using the direct code, the SF-7-4-2-1-0 system, or the random number system. This was done so that

* Marguerite Bebbington, chairman; Hugh P. Godard, Norman Hackerman, Robert D. Misch, Ivy M. Parker.

the user may employ any of these systems to expand the coding of subjects in his particular field.

The NACE system codes the subjects to the third classification. The user may wish to code much deeper. For example, a person who is primarily interested in nonmetallic coatings may wish to use the NACE system for everything except his chosen field. It is practical for him to expand the section on solid organic coatings (NACE No. 5.4.5 with code number 3-12-16-22) so that he can segregate asphalt, bituminous lacquers, etc. He would have the choice of using random number codes 29-56, 57-72 or 29-78. Or if he wished to use SF-7-4-2-1-0 system, he could use the bottom row of card and have 9999 code numbers from which to select. He also could use holes 29-78 for a direct sort method. Similarly, the user could disregard the NACE coding and set up his own system based on any of the above methods. His primary advantage would be obtained from use of random numbers 1-78.

The Random Number System of Coding

The number of combinations available is given from the formula⁶

$$C_n^m = \frac{m!}{n!(m-n)!}$$

where C = number of combinations
m = largest number in code
n = size of code, i.e., 4 numbers

For four number code and 28 holes as used in NACE code, 20,475 combinations are possible. For four number code and 56 holes there would be 367,290 combinations and for 78 holes the possible combinations would exceed one million.

The important parameters in a random number punch code are:

1. The total number of holes available
2. The code length
3. The number of cross references to be punched

The punching of multiple references introduces "confusion" into the system due to overlapping codes, and produces unwanted cards. The number of these can be calculated for any set system.

Coworkers⁷ of Dr. Godard devised formula for the calculations. Table I shows the number of unwanted cards to be expected when using a four number code.

TABLE I

Total No. Holes	No. Cross References	UNWANTED CARDS	
		Percent	No. per 1000 Cards Sorted
28	3	1.24	12.4
28	4	3.37	33.7
28	5	6.67	66.7
28	6	11.33	113.3
56	6	1.35	13.5
56	7	2.28	22.8
56	8	3.34	33.4
56	9	5.01	50.1
73	8	1.50	15.0
73	9	2.18	21.8
73	10	3.09	30.9

NACE has chosen the 28 hole, 4 code, 4 cross reference system because sorting can be done in one operation and its Central Office will use extra holes for other purposes. Many cards have less than four cross references and a large number will have none, so it has been arbitrarily decided that when neces-

sary five cross references can be coded. If more than five are needed, two cards will be produced.

It is apparent, however, that user can reduce number of unwanted cards and increase his field of cross references by using a larger number of holes.

This brief report on use of random numbers has been included to demonstrate their potentialities. Details of a procedure for selecting random numbers may be found in NACE Publication 51-6.

Summary

The literature on corrosion is widely distributed. The recognition of the need for some localization of this information and the attempts to supply this need have been discussed. It is believed that the abstract program outlined will promote a better understanding of the subject, save investigators countless hours of searching and in the long run conserve materials.

Books on Corrosion

The number of books on corrosion is somewhat limited. Some of those generally available are listed below:

1. Bibliography of the Corrosion of Metals and Its Prevention—N. Van Patton, 1923.
2. The Causes and Prevention of Corrosion—A. A. Politt, 1924.
3. Corrosion—Its Causes and Prevention—F. N. Speller, 1st Ed. 1926, 2nd Ed. 1935, 3rd Ed. 1951. (McGraw-Hill, N. Y.)
4. Corrosion of Metals—U. R. Evans, 1926. (Arnold, London.)
5. A Bibliography of Metallic Corrosion—W. H. J. Vernon, 1928.
6. Stainless Iron and Steel—J. H. G. Monypenny, 1931. (Chapman Hall, Eng.)
7. Review of Oxidation and Scaling of Heated Solid Metals—J. S. Dunn and F. J. Wilkins, 1935. (Dept. Sci. Ind. Res., Eng.)
8. Corrosion Resistance of Metals and Alloys—R. J. McKay and R. Worthington, 1936. (Reinhold, N. Y.)
9. Metallic Corrosion, Passivity and Protection—U. R. Evans, 1st Ed. 1937, 2nd Ed. 1946. (Arnold, London; and Longmans, Green, N. Y.)
10. Soil Corrosion—S. Ewing, 1938. (Amer. Gas. Assn.)
11. The Electrode Potential Behavior of Corroding Metals in Aqueous Solutions—O. Gatty and E. C. R. Spooner, 1938. (Clarendon Press, Oxford.)
12. The Corrosion of Iron and Steel—J. C. Hudson, 1940. (Chapman Hall, Eng.)
13. Proceedings First Annual Meeting of The National Association of Corrosion Engineers—NACE, 1944. (NACE, Houston.)
14. Corrosion of Metals—ASM, 1946. (ASM, Cleveland.)
15. An Introduction to Metallic Corrosion—U. R. Evans, 1948. (Arnold, London.)
16. Corrosion Handbook, H. H. Uhlig, Editor in Chief, 1948. (John Wiley, N. Y.)
17. Bibliographic Survey of Corrosion—1945—Robert D. Misch, James T. Waber, and Hugh J. McDonald, 1948. (NACE, Houston.)
18. Thermodynamics of Dilute Aqueous Solutions—M. J. N. Pourbaix, 1949. (English Translation—Arnold, London.)
19. Bibliographic Survey of Corrosion—1946-1947, National Association of Corrosion Engineers, 1951. (NACE, Houston.)

An incomplete list of books on paints and coatings is given below:

1. Chemistry and Technology of Paints—M. Toch, 1926. (Crosby Lockwood.)
2. Protective Metallic Coatings—H. S. Rawdon, 1928. (Chemical Catalog Co.)
3. Protective Films on Metals—E. S. Hedges, 1937. (Chapman Hall, Eng.)
4. Chemistry of Synthetic Surface Coatings—W. Krumbhaar, 1937. (Reinhold, N. Y.)

5. Protective Coatings for Metals—R. M. Burns and A. E. Schuh, 1939. (Reinhold, N. Y.)
6. Protection of Iron and Steel—J. C. Judson, 1940. (Chapman Hall, Eng.)
7. Metal Finishing Guidebook—Directory, 19th Annual Edition, 1950. (Finishing Publications, Inc., N. Y.)

References

1. Corrosion Handbook, H. H. Uhlig, Editor in Chief, 1948 (John Wiley, N. Y.).
2. The Corrosion of Iron, W. R. Whitney. *J. Am. Chem. Soc.* **25**, 394-406 (1903); *Corrosion*, **3**, 331-340 (1947).
3. The Cost of Corrosion to The United States, Herbert H. Uhlig. *Chem. Eng. News*, **27**, 2764-67 (1949); *Corrosion*, **6**, 29-33 (1950).
- 3a. Guide to NACE Corrosion Abstract Punch Card System. National Association of Corrosion Engineers, Houston, Texas.
4. Punch Card Techniques and Applications, R. S. Casey, C. F. Bailey and J. Cox. *J. Chem. Ed.*, **23**, 495-499 (1946) Oct.
5. ASM-SLA Metallurgical Literature Classification, American Society for Metals and Special Libraries Association, 1950. (American Society for Metals, Cleveland).
6. Probability and Its Engineering Uses, T. C. Fry, 1928 (D. Van Nostrand Co., N. Y.).
7. R. H. Hay and J. Mead—unpublished.



Discussions

Materials of Construction for Handling Sulfuric Acid. TP-5A—Materials, Handling and Manufacturing Sulfuric Acid. NACE Technical Practices Committee Report. Publication 51-2. *Corrosion*, **6**, No. 8, 279-282 (1951) Aug.

Discussion by Kempton H. Roll, Lead Industries Association, New York:

Lead is very often taken for granted in discussions about materials of construction in the chemical industry. Perhaps this is so because its use has been recognized for so long a period of time, actually dating back to the very beginning of the sulfuric acid industry. Oftentimes lead is unconsciously ignored because it has become an acceptable criterion while other materials which have been introduced more recently, are less known, at least so far as their performance characteristics are concerned. In addition, they are being aggressively promoted and consequently drawn more forcibly to the attention of corrosion engineers.

Perhaps for the above reasons the TP-5A Committee report on materials of construction for handling sulfuric acid may inadvertently create a misleading and erroneous impression in the minds of engineers who might use it by passing lightly over lead, the principal material of construction with sulfuric acid. Despite the introduction of other materials, lead retains its prominence in practically all the major sulfuric acid consuming industries including the manufacture of superphosphate and phosphoric acid, rayon, alum, sulfur dioxide, acids and other chemicals, in oil refining, pickling, plating, electrolytic recovery of copper, zinc, etc. It is to everyone's benefit, especially the corrosion engineer who may be guided by the report in the solution of his problems, that the true facts be given their proper emphasis.

The use of lead for corrosives handling is partly due to the inherent desirable characteristics of lead as a corrosion resistant material but it is also due to the experience gained from long and varied use of lead in this field. This experience has taught where and how lead may be used to best advantage and

has led to improvements in construction and in installation methods which have kept pace with developments in the chemical and process industries.

The function of lead as a corrosion resistant material for use with sulfuric acid may be summarized briefly as follows:

1. It owes its corrosion resistance in practically all cases to the formation of an insoluble adherent film of lead salts which form upon contact with the acid.

2. The thickness of lead used in chemical equipment is commonly from 3/16 to 1/4 inch. Other corrosion resistant materials, particularly metals, seldom approach this thickness. This distinction is significant because of the common tendency to judge best performance on the basis of the lowest rate of penetration. In the case of lead, this practice is oftentimes misleading for it fails to take into consideration two important factors: a) the greater thickness of lead means a correspondingly longer service life, providing pitting is not encountered, b) the rate of corrosion substantially decreases once the protective film mentioned above has formed.

3. How and in what manner lead is used has an all-important bearing on how much service can be expected from it under a given set of conditions. Depending upon temperature, pressure, time-temperature cycle, abrasion, heat transfer and corrosives involved, lead may be specified as loose sheet lined, strapped sheet lined, cage construction, bonded lead lined, brick and lead lined or cast. Below is a drawing showing the various methods of modern lead construction.

4. Composition of the lead is likewise important. Three types of lead are used with sulfuric acid. a) Chemical lead is the grade most commonly used with sulfuric acid. It contains .04 to .08 percent copper and .002 to .02 percent silver, both of which improve lead's fatigue and creep resistance without detracting from its corrosion resistance. Chemical lead is recommended for use up to 450 degrees F. b) Antimonial lead or "hard" lead is a common alloy of lead and antimony containing anywhere from 2 to 12 percent

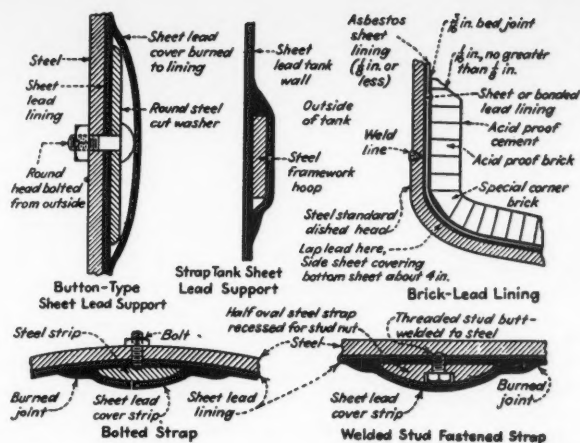


Figure 1—Showing various methods of lead construction.

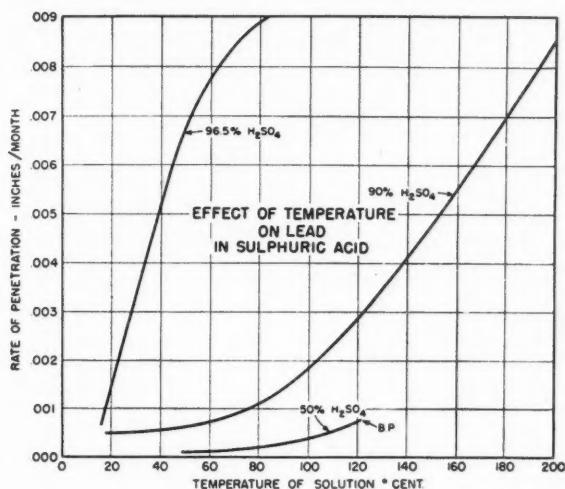


Figure 2

antimony to make the lead harder and stronger. It does not improve corrosion resistance, at least so far as sulfuric acid is concerned. It melts at a lower temperature so that it is not recommended for use above 250 degrees F. c) Tellurium lead is usually chemical lead alloyed with 0.05-0.06 percent tellurium. The tellurium is claimed to improve the work hardening

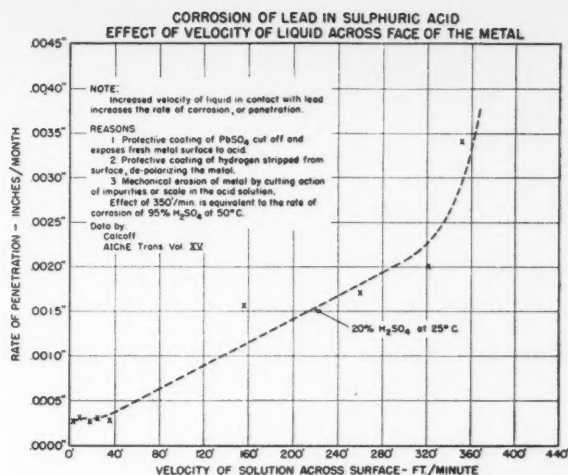


Figure 3

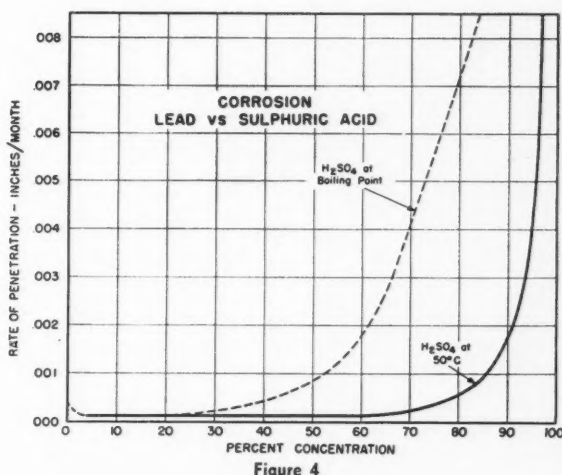


Figure 4

characteristics of lead which ordinarily is self-annealing at room temperature.

The following graphs show the corrosion resistance of lead with sulfuric acid under various conditions of temperature and concentration, the effect of temperature on lead in sulfuric acid and the effect of the velocity of sulfuric acid across the face of lead.

first choice for **PERMANENCE**

SOMASTIC[★]

REG. U.S. PAT. OFF.

PIPE COATING

★ Data on the life expectancy of SOMASTIC Pipe Coating is limited only by the 20 years it has been in existence, giving trouble-free service at locations where corrosion formerly required costly maintenance and replacements.

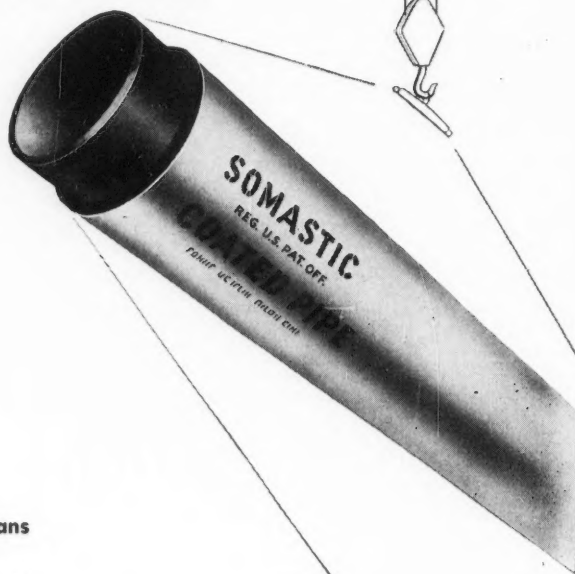
Through experience gained in SOMASTIC-coating thousands of miles of lines, 2 alternative application methods have been developed:

... by Central Plant

... by portable Railhead Plant

One of these methods offers the economical means of safeguarding your pipe line investment.

SOMASTIC IS The Best PIPE COATING



Positive protection is assured by the physical characteristics of this thick, impervious asphalt-mastic coating, tightly bonded to the pipe, and made continuous by overlapping field joints molded of the same material. Write for more detailed information.



MANUFACTURED BY

**BECHTEL
CORPORATION**
SAN FRANCISCO and
WILMINGTON, CALIFORNIA

*In the 11 Western States
and in Foreign Countries*

H. C. PRICE CO.
BARTLESVILLE, OKLAHOMA
PHILADELPHIA, PA.
NEW ORLEANS, LA.

*In the 37 States East of the
Rocky Mountains*

CORROSION

Official Publication

NATIONAL ASSOCIATION
OF
CORROSION ENGINEERS



VOLUME 7

JANUARY THROUGH DECEMBER

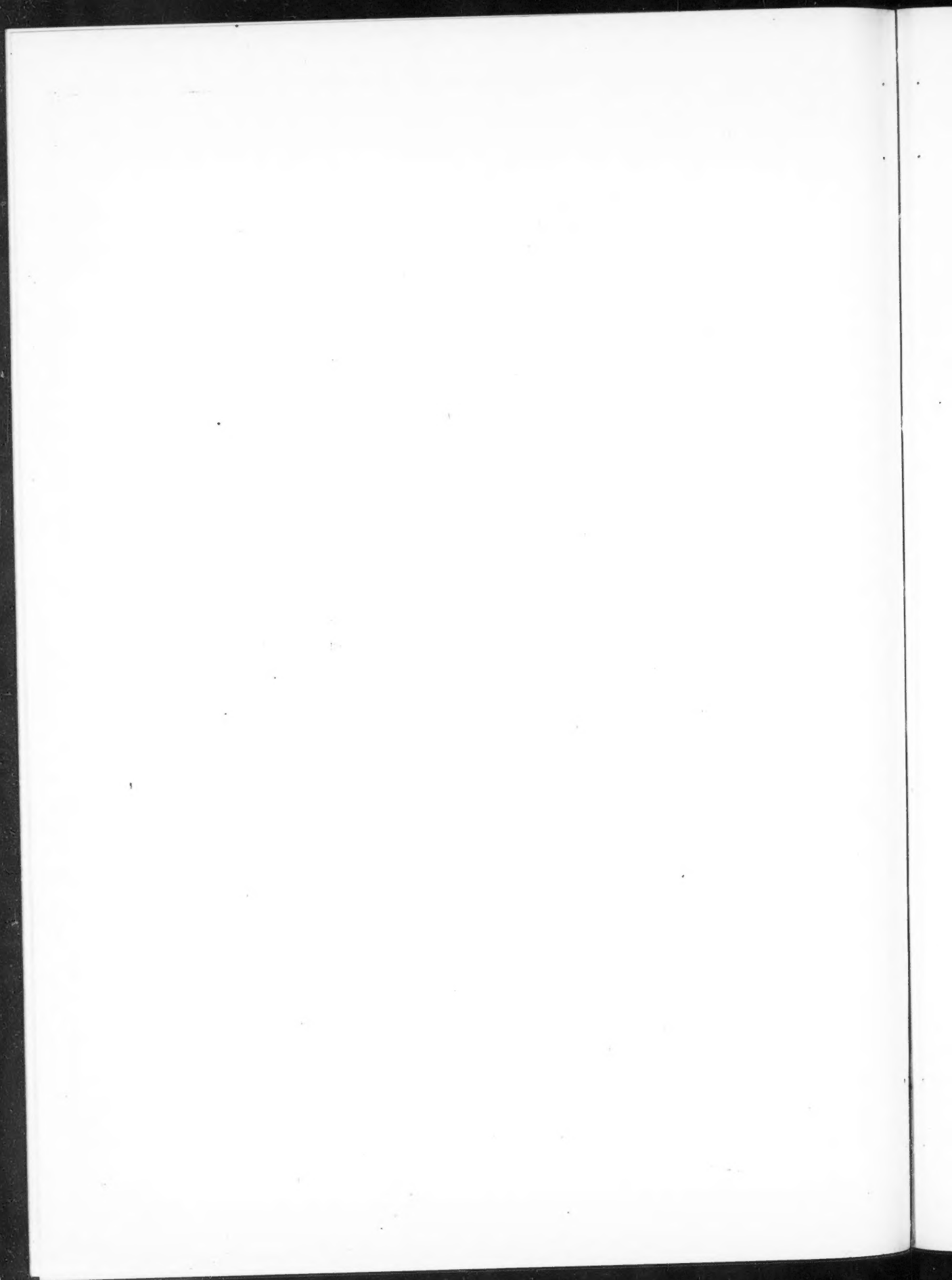
1951



EDITORIAL AND BUSINESS OFFICES
919 MILAM BLDG., HOUSTON, TEXAS



(Contents of the Issues Included in This Volume Are Copyrighted and May Not Be Used
Without Permission of the Association)



INDEX TO TECHNICAL MATERIAL

CORROSION

VOLUME 7

JANUARY 1 - DECEMBER 31

1951

C O N T E N T S

Tabular Cross Index to Subject Matter
Which Includes:

1. Contents chronologically
2. Contents in page sequence

Authors, Alphabetically

Topical Index to Corrosion Abstracts

PAGE NUMBERS BY MONTHS

Pages		Pages	
1- 40	January	211-252	July
41- 74	February	253-282	August
75-112	March	283-320	September
113-144	April	321-360	October
145-178	May	361-408	November
179-210	June	409-456	December

INDEX HEADINGS

From the Abstract Filing Index Compiled by the Abstract Committee, National Association of Corrosion Engineers

(Revision as of June, 1951)

History of Index—The project of originating a topical index under which abstracts dealing with corrosion can be classified was begun by the NACE Abstract Committee in January, 1947, under the chairmanship of Mrs. Lorraine Voigt Peloubet. This index, in the revision dated June, 1951, is the one used herein for the purpose of cross-indexing technical articles published in CORROSION in the year 1951.

Description of Index—First column of the tabular index contains the titles and authors of technical articles published in CORROSION arranged chronologically by year and month (Volume and Issue) and the number of the page on which the listed article begins. Discussions are listed only when separated from the article to which they refer. Each of the eight major columns to the right is numbered to correspond to the primary subject in the Abstract Filing Index. Within each of the major columns are numbered columns cor-

responding to the sub-topic or secondary subject of the topical index. When the subject matter of an article falls into the topic indicated by any of the first two index numbers, a check mark is placed in the column. Under the alphabetical index of authors, each author's contributions are indexed by year and page number.

How to Use Index—To discover the subject matter of a known article, first find the article in the left hand column, search horizontally to the check mark(s), then to column headings to learn the secondary and primary topical classification numbers; then refer to the index to learn the topic corresponding to the numbers. To search for a topic in an unknown article, first refer to the index and note the two numbers corresponding to the topic. Refer to the column headings of the table, find the major and minor columns corresponding to the number, and trace down vertically until a check mark is reached, then search horizontally to the title of the article to which the check mark refers.

1. GENERAL

1. Miscellaneous
 2. Importance
 1. General
 2. Economics
 3. Effect on Specifications
 4. Prevention in National Defense
 5. Safety and Toxicity
 6. Other
 3. Reviews
 4. Bibliographies
 5. Directories of Material
 6. Books
 7. Organized Studies of Corrosion
 1. Organizations
 - a. General
 - b. Government cooperative activities
 - c. Technical committee activities
 - d. Other
 2. Test Sites
 3. Other
 8. Personalities and Directories of Individuals

2. TESTING

1. General
 1. Calculations and Statistics
 2. Criteria for Evaluation
 3. Other
2. On Location Tests
 1. General
 2. Atmospheric Exposure
 3. Service, Evaluation of Materials
 4. Service, Testing of Equipment
 5. Service, Testing of Coatings
 6. Soil Exposure (including surveys)
 7. Waters
 8. Other
3. Laboratory Methods and Tests
 1. General
 2. Accelerated Tests
 - a. General
 - b. Cu strip
 - c. Drop test
 - d. Intergranular test
 - e. Weathering
 - (1) General
 - (2) Spray
 - (3) Exposure to light
 - (4) Other
 - f. Other
 3. Biological Control
 4. Chemical Methods
 - a. General
 - b. Immersion
 - (1) General
 - (2) Alternate
 - (3) Partial
 - (4) Total
 - c. Method of analyses
 - d. Other
 5. Electrochemical and Electrical Methods
 - a. General
 - b. Galvanic couples
 - c. Potential measurements
 - d. Other
 6. Surface Examination
 - a. General
 - b. Electron microscope
 - c. Etching techniques
 - d. Optical methods
 - e. Other

2. TESTING—Continued

7. Physical Methods
 - a. General
 - b. Adhesion, permeability, thickness and hardness tests for coating
 - c. Erosion testing
 - (1) General
 - (2) Abrasion
 - (3) Cavitation-Erosion
 - (4) Erosion-Corrosion
 - (5) Impingement
 - (6) Velocity
 - (7) Other
 - d. Stress corrosion testing
 - (1) General
 - (2) Caustic embrittlement
 - (3) Fatigue
 - (4) Fretting
 - (5) Season cracking
 - (6) Other
 - e. Temperature
 - (1) General
 - (2) Differential (thermogalvanic)
 - (3) High
 - (4) Low
 - (5) Thermal shock
 - (6) Other
8. Pilot Plant
9. Special Techniques
 - a. General
 - b. Electrographic
 - c. Magnetic methods
 - d. Microbalance
 - e. Micrographic
 - f. Polarographic
 - g. Radioactive tracers
 - h. Radiation methods
 - (1) Gamma ray
 - (2) Electron diffraction
 - (3) X-ray technique
 - i. Other
10. Other
4. Instrumentation
 1. General
 2. Corrosion Test Instruments or Equipment
 3. Non-destructive Inspection Methods
 4. Other
5. Specifications and Standardization
6. Preparation and Cleaning of Specimens
7. Other

3. CHARACTERISTIC CORROSION PHENOMENA

1. General
2. Forms
 1. General
 2. Localized Attack
 - a. General
 - (1) Local elements
 - (2) Theory and mechanism
 - (3) Other
 - b. Compositional changes
 - (1) General
 - (2) Carburelizing
 - (3) Dezincification
 - (4) Embrittlement
 - (a) Hydrogen (not caustic)
 - (b) Other
 - (5) Graphitic corrosion
 - (6) Nitriding
 - (7) Other

3. CHARACTERISTIC CORROSION PHENOMENA (Continued)

- c. Cracking
 - (1) General
 - (2) Intergranular
 - (3) Transgranular
- d. Pitting
- e. Other
3. Uniform Attack
 - a. General
 - b. Films
 - (1) General
 - (2) Theory and mechanism
 - (3) Other
 - c. Other
 4. Other
3. Biological Effects
 1. General
 2. Fouling
 3. Macro-organisms
 4. Micro-organisms
 - a. General
 - b. Aqueous environment
 - c. Soil environment
 - d. Other
 5. Other
4. Chemical Effects
 1. General
 2. Catalytic Effects
 3. Composition of Corrosion Products
 4. Concentration (not conc. cells)
 5. Ionization
 6. Oxygen and Other Gases
 7. pH
 8. Specific Ions
 9. Water and Water Vapor
 10. Other
5. Physical and Mechanical Effects
 1. General
 2. Deposits
 3. Erosion
 - a. General
 - b. Abrasion
 - c. Cavitation
 - d. Erosion-Corrosion
 - e. Impingement
 - f. Other
 4. Light
 5. Permeability of Films and Coatings
 6. Porosity of Metals
 7. Pressure
 8. Stress
 - a. General
 - b. Cyclic
 - (1) General
 - (2) Fatigue
 - (3) Fretting
 - (4) Other
 - c. Internal stress
 - d. Static
 - (1) General
 - (2) Caustic embrittlement
 - (3) Season cracking
 - (4) Other
 - e. Other
 9. Temperature
 - a. General
 - b. Differential (thermogalvanic)
 - c. High
 - d. Low
 - e. Thermal shock
 - f. Other
 10. Time
 11. Velocity
 12. Other

3. CHARACTERISTIC CORROSION PHENOMENA (Continued)

6. Electrochemical Effects
 1. General
 2. Concentration Cells
 - a. General
 - b. Crevice corrosion
 - c. Differential aeration
 - d. Other
 3. Conductivity & Resistivity
 4. Contact Potentials
 5. Electro-motive Force
 - a. General
 - b. EMF series
 - c. Redox potential
 - d. Solution potential
 - e. Other
 6. Galvanic Effects—Bimetallic Contact
 7. Long-line Currents
 8. Polarization and Overvoltage
 - a. General
 - b. Depolarizers
 - c. Hydrogen overvoltage
 - d. Oxygen overvoltage
 - e. Other
 9. Stray Currents
 10. Other
7. Metallurgical Effects
 1. General
 2. Alloying Elements
 3. Fabrication and Heat Treatment
 - a. General
 - b. Heat treatment
 - c. Joints
 - (1) General
 - (2) Brazed
 - (3) Riveted
 - (4) Soldered
 - (5) Welded
 - (6) Other
 - d. Shaping and fabrication
 - e. Other
 4. Metallic Structure
 - a. General
 - b. Grain boundaries and size
 - c. Orientation
 - d. Other
 5. Other
8. Miscellaneous Principles
 1. General
 2. Electrochemical Theory
 3. Passivity
 - a. General
 - b. Experimental evidence
 - c. Theories
 - d. Other
 4. Other
9. Other

4. CORROSIVE ENVIRONMENTS

1. General
2. Atmospheric
 1. General
 2. Arctic
 3. Flue and Stack Gases
 4. Industrial
 5. Marine
 6. Rural
 7. Tropical
 8. Urban

3. CHARACTERISTIC CORROSION PHENOMENA (Continued)

3. Chemicals, Inorganic

1. General
2. Acids, Acid Anhydrides, Acid Salts
3. Bases, Basic Anhydrides, Basic Salts
4. Mixtures
5. Non-metallic Elements
6. Salts
7. Other

4. Chemicals, Organic

1. General
2. Acids
3. Alcohols
4. Carbohydrates
5. Halide Compounds
6. Hydrocarbons
7. Mixtures
8. Nitrogen Compounds
9. Sulfur Compounds
10. Other

5. Soil

1. General
2. Types
 - a. General
 - b. Clay
 - c. Salt mud
 - d. Sandy
 - e. Other
3. Surveys (See 2.2.6)
4. Other

6. Water and Steam

1. General
2. Boiler and boiler feed water, and steam condensate
3. Brackish waters
4. Cooling waters
5. Distilled and demineralized waters
6. Domestic waters
7. Fresh water
8. Mine waters
9. Oil well brines
10. Refrigeration brines
11. Sea water
12. Sub-surface injection water (oil fields)
13. Waste waters and sewage
14. Other

7. Molten Metals

8. Other

5. PREVENTIVE MEASURES

1. General

2. Cathodic Protection

1. General
2. Anodes—Sacrificial (galvanic)
 - a. General
 - b. Magnesium
 - c. Zinc
 - d. Other
3. External Current Source
 - a. General
 - b. Anodes
 - c. Engine and Other Generators
 - d. Rectifiers
 - e. Other
4. Criteria of Protection
5. Other

3. Metallic Coatings

1. General
2. Specific Coating
 - a. General
 - b. Aluminum
 - c. Cadmium
 - d. Chromium
 - e. Copper
 - f. Gold
 - g. Indium
 - h. Lead
 - i. Magnesium
 - j. Manganese
 - k. Molybdenum
 - l. Nickel
 - m. Silver
 - n. Tin
 - o. Tungsten
 - p. Zinc
 - q. Other
3. Specifications
4. Techniques
 - a. General
 - b. Cladding
 - c. Chemical Reduction
 - d. Diffusion Alloying
 - (1) General
 - (2) Calorizing
 - (3) Corroding
 - (4) Sheradizing
 - (5) Other
 - e. Electrodeposition
 - f. Hot Dip
 - (1) General
 - (2) Lead
 - (3) Tin
 - (4) Zinc (galvanizing)
 - (5) Other

5. PREVENTIVE MEASURES (Continued)

- g. Tinning
- h. Vaporizing—Metalizing
- i. Other
5. Other

4. Non-metallic Coatings and Paints

1. General
2. Inorganic Coatings
 - a. General
 - b. Cementiferous
 - c. Natural oxide
 - d. Porcelain
 - e. Silicate base
 - f. Other
3. Linings
4. Removers (See 5.9.2)
5. Solid Organic Coatings
 - a. General
 - b. Asphalt
 - c. Bituminous
 - d. Lacquers
 - e. Primers
 - f. Plastics
 - (1) Thermoplastic
 - (2) Thermosetting
 - g. Strip-off materials
 - h. Other
6. Specifications
7. Techniques of Application
 - a. General
 - b. Baking
 - c. Brush
 - d. Flame spray
 - e. Mechanical Spray
 - f. Steam spray
 - g. Other
8. Uses
 - a. General
 - b. Acid-resistant
 - c. Alkali-resistant
 - d. Anti-fouling
 - e. Decorative
 - f. Fire retardant and heat resistant
 - g. Weather resistant
 - h. Other
9. Other

5. Oil and Grease Coatings

1. General
2. Heavy greases
3. Preservative oils
4. Other

6. Packaging

1. General
2. "Cocoon" Method
3. Other

7. Treatment of Medium

1. General
2. Aeration
3. Deaeration
4. Dehumidification
5. Desalting
6. Ion Exchange
7. pH Control
 - a. General
 - b. Neutralization
 - c. Other
8. Sequestering Agents
9. Addition
9. Other

8. Inhibitors and Passivators

1. General
2. Application
3. Mechanism
4. Types
 - a. General
 - b. Inorganic
 - c. Organic
5. Other

9. Surface Treatment

1. General
2. Chemical and electrochemical cleaning
 - a. General
 - b. Caustic cleaning
 - c. Electrolytic cleaning
 - d. Hydride descaling
 - e. Pickling (acid cleaning)
 - f. Vapor-phase and solvent cleaning
 - g. Other
3. Mechanical Cleaning
 - a. General
 - b. Barrel finishing
 - c. Flame cleaning
 - d. Sand and shot blasting
 - e. Shot peening
 - f. Vapor blasting
 - g. Other
4. Surface Conversion
 - a. General
 - b. Anodizing
 - c. Chromatizing
 - d. Electropolishing
 - e. Phosphatizing
 - f. Other
5. Other

10. Other

6. MATERIALS OF CONSTRUCTION

1. General

2. Ferrous Metals and Alloys

1. General
2. Iron
 - a. General
 - b. Cast
 - c. Electrolytic
 - d. Wrought
 - e. Other
3. Steel, Plain Carbon
4. Low Alloys
5. High Alloys
6. Other

3. Non-ferrous Metals and Alloys—Heavy

1. General
2. Cadmium
3. Chromium
4. Cobalt and cobalt alloys
5. Columbium (Niobium)
6. Copper and copper alloys
 - a. General
 - b. Copper
 - c. Cu-Zn alloys
 - d. Cu-Ni alloys
 - e. Cu-Sn alloys
 - f. Cu-Si alloys
 - g. Cu-Be alloys
 - h. Other
7. Indium and indium alloys
8. Lead and lead alloys
9. Molybdenum
10. Nickel and nickel alloys
 - a. General
 - b. Nickel
 - c. Ni-Cu alloys
 - d. Ni-Cr alloys
 - e. Ni-Mn alloys
 - f. Ni-Mo and Ni-Mo-Fe (Cr) alloys
 - g. Other
11. Noble metals and alloys
 - a. General
 - b. Gold
 - c. Palladium
 - d. Platinum
 - e. Rhodium
 - f. Silver
 - g. Other
12. Rhenium
13. Tantalum
14. Tin
15. Titanium
16. Tungsten (Wolfram)
17. Uranium
18. Vanadium
19. Zinc
20. Zirconium
21. Other

4. Non-ferrous Metals and Alloys—Light

1. General
2. Aluminum and Aluminum Alloys
3. Beryllium
4. Magnesium and Magnesium Alloys
5. Other

5. Metals—Multiple or Combined Discussion

6. Non-Metallic Materials

1. General
2. Asbestos
3. Boron
4. Carbon, Graphite, and Impregnated Materials
5. Cement and Concrete
6. Ceramics
 - a. General
 - b. Brick
 - c. Glass and vitreous silica
 - d. Stone and stoneware
 - e. Other
7. Natural and Synthetic Rubber
 - a. General
 - b. Natural
 - c. Synthetic
 - d. Mixtures
 - e. Other
8. Plastic (other than rubber)
 - a. General
 - b. Thermosets
 - (1) Phenolics
 - (2) Ureas
 - (3) Melamines
 - (4) Polyesters
 - c. Thermoplastics
 - (1) Cellulosics
 - (a) Nitrates
 - (b) Acetates
 - (c) Butyrates
 - (d) Ethyls
 - (2) Synthetics
 - (a) Vinyls
 - (b) Acrylics
 - (c) Polystyrenes

6. MATERIALS OF CONSTRUCTION (Continued)

- (d) Nylons
- (e) Polyethylenes
- d. Specialties
 - (1) Silicones
 - (2) Fluorocarbons
 - (3) Electroplastics
9. Silicon
10. Textile
11. Wood
12. Other

7. Duplex Materials

1. General
2. Ceramics-Metals
3. Duplex Metallic Materials
4. Other

8. Other

7. EQUIPMENT

1. Engines, Bearings, and Turbines

2. Valves, Pipes, and Meters

3. Pumps, Compressors, Propellers, and Impellers

4. Heat Exchangers

1. General
2. Coils and Condensers
3. Sprays
4. Other

5. Containers

1. General
2. Cans
3. Caskets
4. Gas Holders
5. Tanks
6. Other

6. Unit Process Equipment

1. General
2. Agitators
3. Autoclaves
4. Rollers
5. Concentrators
6. Digestors
7. Filters
8. Fractionating Towers
9. Other

7. Electrical Telephone and Radio

8. Wires and Cables (non-electrical)

9. Specifications

10. Other

8. INDUSTRIES

1. Group 1

1. Air Conditioning
2. Architecture and Building
3. Refrigeration
4. Sewage and Water

2. Group 2

1. Communications

3. Group 3

1. Agriculture
2. Beverage
3. Dairy
4. Fermentation
5. Food
6. Sugar
7. Starch

4. Group 4

1. Fuel
2. Gases
3. Petroleum Refining and Production
4. Rubber

5. Group 5

1. Ceramics
2. Glass
3. Pulp and Paper
4. Wood Products

6. Group 6

1. Laundry
2. Soap and Synthetic Detergents
3. Textiles

7. Group 7

1. Graphic Arts
2. Instruments
3. Jewelry
4. Photography

8. Group 8

1. Chemical Manufacturing
2. Distilled Liquor
3. Electroplating
4. Leather and Tanning
5. Metal Fabrication and Finishing
6. Pharmaceuticals

9. Group 9

1. Aircraft
2. Automotive
3. Pipe Line
4. Railroad
5. Shipping

10. Group 10

1. Explosives
2. Metallurgy
3. Mining
4. Ordnance and War Materials
5. Other

1951

January—Vol. 7—No. 1

Objectives and Progress of TP-2—Galvanic Anodes for Cathodic Protection—By Walter P. Nostr.....	1																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									</
---	---	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	----

February—Vol. 7—No. 2

Objectives of Technical Practices Committee 3—Anodes for Impressed Currents—By Donald H. Bond.....	41																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										</
--	----	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	----

1951

April—Vol. 7—No. 4

Technical Practices Committee 15—Corrosion Control in the Transportation Industry—By M. A. Williamson	113
Cathodic Protection of an Active Ship in Sea Water. Part II—By K. N. Barnard	114
Discussion: 1951, p. 405.	
Porcelain Enamels as a Corrosion Resistant Coating for Metals—By G. H. Melby	118
Literature Survey on Corrosion in Neutral Unarated Oil Well Brines—By H. R. Copson	123
Corrosion Resistant Equipment for the Corn Refining Industry—By R. W. Flouny	129
Tower Footing Corrosion—By Walter J. Piper and John D. Piper	134
Discussion: 1951, p. 360.	
Discussion—Application of Corrosion Resisting Materials to Railroad Electrical Construction—By H. P. Godard	141
Discussion—The Role of Polarization in Electrochemical Corrosion—By J. V. Petrecci	142
Condensation of Oil and Gas Well Equipment Committee No. 1—Corrosion of Oil and Gas Well Equipment	144

May—Vol. 7—No. 5

Objectives and Progress of Technical Practices Committee 9—Corrosion Inhibitors—By A. Wachter.....	145
A Polarographic Method for the Continuous Determination of the Consumption of Oxygen in Corrosion Tests—By Paul Delaty.....	146
The Chemical Resistance of Phenolic Resins—By Raymond B. Seymour.....	151
Current Requirements for the Cathodic Protection of Steel in Dilute Aqueous Solutions—By G. R. Klein and E. J. Wilhelm Discussion: 1951, p 465.....	156
Corrosion Problems Related to Air Transport Aircraft—By O. E. Kirchner and F. M. Morris.....	161

June—Vol. 7—No. 6

TP-2	Phase Publication of Bulletin On Corrosion at Elevated Temperatures—By M. A. Schell	179
	 Resin Amine-Ethylene Oxide Condensates as Corrosion Inhibitors for Mild Steel in Hydrochloric Acid—By Edward A. Bred and Harry W. Whitcomb	189
	 Discussion: 1931, p. 603.	
	 Testing Inhibitors of Brine Drippings Corrosion of Railway Tracks and Equipment—By G. M. Magee	186
	 Discussion: 1931, p. 316.	
	 Some Applications of Corrosion Inhibitors in the Petroleum Industry—By Charles M. Einar, Jr.	189
	 Discussion: 1931, p. 316.	
	 Corrosion of Railroad Hopper Car Body Sheets—By H. J. Kelly	196
	 Cathodic Protection Technical Practices Bulletin III prepared by Correlating Committee on Cathodic Protection	202
	 Erratum, p. 326.	
	 Discussion: The Use of Cathodic Protection in Conjunction with Paint Coatings—By G. A. Works	209

Alphabetical Index to Authors

CORROSION, Vol. 7, 1951

	Yr.	Pp.		Yr.	Pp.		Yr.	Pp.
A			C			F		
Ackoff, Albert K. Discussion—Materials of Construction for Handling Sulfuric Acid.....	51	318	Case, L. C. Control of Sour Crude Corrosion in Kansas Production Operations.....	51	390	Ferree, J. A., see Renshaw, W. G.		
Aitken, P. M. Discussion—Cathodic Protection of an Active Ship in Sea Water—Part II, with G. L. Christie.....	51	405	Casey, J. Pat, Jr. Discussion—Sodium Hydroxide as an Inhibitor of Pitting in 18-8 Stainless Steel.....	51	421	Flournoy, R. W. Corrosion Resistant Equipment for the Corn Refining Industry....	51	129
Allen, E. R., see Rogers, Walter F.			Chen, P. C., see Straumanis, M. E.			Fontana, M. G. Discussion—Corrosion Problems in the Modern By-Products Coke Plant.....	51	84
Anderson, H. H. Selling Management on Corrosion Control.....	51	361	Christie, G. L., see Aitken, P. M.			Also see Holzworth, M. L.		
Anonymous Be An Active Member.....	51	75	Comeaux, Roy V. Discussion—The Passivating Characteristics of the Stainless Steels.....	51	400	G		
Condensation of Report of Technical Practices Committee No. 1—Corrosion of Oil and Gas Well Equipment.....	51	144	Compton, K. G. Filamentary Growths on Metal Surfaces—"Whiskers," with A. Mendizsa & S. M. Arnold.....	51	327	Gegner, P. J., see Schmidt, H. W.		
Cathodic Protection Technical Practices, Bulletin III Prepared by Correlating Committee on Cathodic Protection.....	51	202	Effect of Packaging on Corrosion of Zinc Plated Equipment, with S. M. Arnold & A. Mendizsa....	51	365	Glas, D. C. Economics of Rectifier Installation for Cathodic Protection of a Bare Pipe Line.....	51	322
Punch Cards Are Latest Abstract Service to Be Provided by NACE.....	51	211	Cook, Leon D., Jr. Discussion—Stress Corrosion Cracking in Alkaline Solutions.....	51	400	Godard, H. P. A New Instrument for Measuring Galvanic Corrosion Currents....	51	93
Armstrong, Clifford B., Jr. Discussion—Corrosion in the Ammonolysis of Aliphatic Chlorides. Discussion—Stress Corrosion Cracking in Alkaline Solutions.....	51	360	Copson, H. R. Literature Survey on Corrosion in Neutral Un-aerated Oil Well Brines.....	51	123	Discussion—Application of Corrosion Resisting Materials to Railroad Electrical Construction....	51	141
Discussion—Sodium Hydroxide as Inhibitor of Pitting in 18-8 Stainless Steel.....	51	421	Effect of Specimen Shape on Corrosion in the Atmosphere.....	51	335	Discussion—Corrosion Aspects of Fusion Welded Aircraft High-Strength Aluminum Alloys....	51	437
Arnold, S. M., see Compton, K. G.			Curry, W. J., see Smith, S. S.			Goldberg, Bernard Flame Sprayed Plastic Coatings..	51	47
B			D			Guy, Arthur M. Discussion—Prevention of Corrosion and Metal Attack in the Steam Water Cycle of the Steam Power Plant.....	51	315
Ballou, J. K. A Proposed Alternative Method for Measuring the Electrical Resistance of Pipe Line Coatings, with R. P. Howell, J. W. Liljeberg & P. F. Offermann.....	51	438	Darrin, Marc Discussion—Testing Inhibitors of Brine Drippings Corrosion of Railway Tracks and Equipment. Discussion—Prevention of Corrosion in Naval Aircraft, Part II. Discussion—Dicyclohexylammonium Nitrite, a Volatile Inhibitor for Corrosion Preventive Packaging..	51	316	H		
Barnard, K. N. Cathodic Protection of an Active Ship in Sea Water, Part II.....	51	114	Davenport, J. A. Ohio River Division Corrosion Problems.....	51	42	Hackerman, Norman Education Committee Aims to Demonstrate Importance of Corrosion Technology.....	51	321
Beck, F. H., see Holzworth, M. L.			Davis, B. H., see Rogers, Walter F.			Hawke, David L., see Elckhoff, Arnold J.		
Beck, Walter Discussion—Some Factors Affecting Paint Performance on Cathodically Protected Steel.....	51	74	Degnan, Thomas F. Discussion—Stress Corrosion Cracking in Alkaline Solutions.....	51	400	Heinemann, G., see Schmidt, H. W.		
Beenfelfdt, E. L., see Diehlman, George			Delahay, Paul A Polarographic Method for the Continuous Determination of the Consumption of Oxygen in Corrosion Tests.....	51	146	Hendrickson, David J. Discussion—Tower Footing Corrosion.....	51	360
Berry, Norton E. NACE—A Virile Vehicle for an Organized Attack on Corrosion..	51	283	Deringer, W. F. Discussion—Porcelain Enamel as a Corrosion Resistant Coating for Metals.....	51	123	Holler, H. D. Studies on Galvanic Couples, Parts I, II & III.....	51	52
Best, George E. Discussion—Prevention of Corrosion in Naval Aircraft, Part II..	51	388	Deuber, Carl G. Discussion—Bacterial Casing Corrosion in the Ventura Field.....	51	319	Holzworth, M. L. The Mechanism of Knife-Line Attack in Welded Type 347 Stainless Steel, with F. H. Beck & M. G. Fontana.....	51	441
Bialosky, J. M., see Mears, R. B.			Diehlman, George Preventing Corrosion with Protective Paint Coatings, with E. L. Beenfelfdt.....	51	88	Horton, James B. Discussion—Stress Corrosion Cracking in Alkaline Solutions.....	51	400
Bilhartz, H. L. High Pressure Sweet Oil Well Corrosion.....	51	256	Dietze, Irwin C. Objectives of TP-16—Electrolysis and Corrosion of Cable Sheaths..	51	253	Howell, R. P., see Ballou, J. K.		
Discussion—Bacterial Casing Corrosion in the Ventura Field.....	51	319	Dix, E. H. Discussion—The Influence of Stress on Corrosion, with R. H. Brown & R. D. Williams.....	51	109	Hugo, L. A. Discussion—Economics of Rectifier Installation for Cathodic Protection of a Bare Pipe Line.....	51	326
Blair, Charles M., Jr. Some Applications of Corrosion Inhibitors in the Petroleum Industry.....	51	189	Doig, Keith Bacterial Casing Corrosion in the Ventura Field, with Aaron Wachter.....	51	212	J		
Discussion—Rosin Amine-Ethylene Oxide Condensates as Corrosion Inhibitors for Mild Steel in Hydrochloric Acid.....	51	403	E			Jacob, John J., Jr. What Management Expects From the Corrosion Engineer.....	51	84
Bond, Donald H. Objectives of Technical Practices Committee 3—Anodes for Impressed Currents.....	51	41	Eberhardt, T. J. Discussion—Tower Footing Corrosion.....	51	360	Jelen, F. C. Discussion—Corrosion in the Ammonolysis of Aliphatic Chlorides..	51	360
Also see Rogers, Walter F.			Elckhoff, Arnold J. Discussion—Some Factors Affecting Paint Performance on Cathodically Protected Steel, with David L. Hawke.....	51	70	K		
Breston, J. N. Discussion—Control of Sour Crude Corrosion in Kansas Production Operations.....	51	396	Ellis, O. B. Area Effects in Crevice Corrosion, with F. L. LaQue.....	51	362	Kehn, G. R. Current Requirements for the Cathodic Protection of Steel in Dilute Aqueous Solutions, with E. J. Wilhelm.....	51	156
Bried, Edward A. Rosin Amine-Ethylene Oxide Condensates as Corrosion Inhibitors for Mild Steel in Hydrochloric Acid, with Harry M. Winn.....	51	180	Evans, U. R. Stress Corrosion: Its Relation to Other Types of Corrosion.....	51	238	Kelly, B. J. Corrosion of Railroad Hopper Car Body Sheets.....	51	196
Briton, S. C. Discussion—Current Requirements for the Cathodic Protection of Steel in Dilute Aqueous Solutions.....	51	403	Also see Whitwham, D.			Kirchner, O. E. Corrosion Problems Related to Air Transport Aircraft, with F. M. Morris.....	51	161
Brown, C. S. Discussion—Materials of Construction for Handling Sulfuric Acid. Discussion—Rosin Amine-Ethylene Oxide Condensates as Corrosion Inhibitors for Mild Steel in Hydrochloric Acid.....	51	317	Ewing, Scott P. Potential Measurements for Determining Cathodic Protection Requirements.....	51	410	Discussion—Prevention of Corrosion of Naval Aircraft, Part II..	51	389
Discussion—Sodium Hydroxide as Inhibitor of Pitting in 18-8 Stainless Steel.....	51	403				Kulman, F. E. Discussion—Bacterial Casing Corrosion in the Ventura Field....	51	319
Brown, R. H., see Dix, E. H.						L		
Buchan, R. C. Discussion—High Pressure Sweet Oil Well Corrosion.....	51	318				LaFever, Mort Discussion—Economics of Rectifier Installation For Cathodic Protection of a Bare Pipe Line....	51	326
						Landau, C. S., Jr. Discussion—Stress Corrosion Cracking in Alkaline Solutions.....	51	400

	Yr.	Pp.		Yr.	Pp.		Yr.	Pp.
LaQue, F. L. Discussion—The Passivating Characteristics of the Stainless Steels 51 The Publications Committee..... 51 Also see Billis, O. B.	51	400	Pascoe, Walter R. , see Seymour, Raymond B.			Shoan, Raymond A. Discussion—Corrosion Problems of Motor Coaches..... 51	307	
Larrabee, C. F. Stainless Steels for the Bottoms of Tanks Containing Sour Crude Oil, with W. F. Rogers..... 51	276		Peabody, A. W. Discussion—Ohio River Division Corrosion Problems..... 51	46		Skel, T. , see Wachter, A.		
Lee, R. P. Discussion—Materials of Construction for Handling Sulfuric Acid..... 51	317		Pearson, J. M. Discussion—International and External Corrosion Experience in Shell's Products Pipe Lines..... 51	27		Smith, L. W. Discussion—Corrosion Problems Related to Air Transport Aircraft 51	177	
Liebhman, A. J. Discussion—Materials of Construction for Handling Sulfuric Acid..... 51	318		Pearson, J. M. Discussion—Potential Measurements for Determining Cathodic Protection Requirements..... 51	417		Smith, S. S. Internal and External Corrosion Experience in Shell's Products Pipe Lines, with W. J. Curry & E. H. Rush..... 51	20	
Liesenow, R. P. Discussion—Porcelain Enamel as a Corrosion Resistant Coating for Metals..... 51	122		Petrocelli, J. V. Discussion—The Role of Polarization in Electrochemical Corrosion..... 51	142		Spaulding, H. C. Discussion—Control of Sour Crude Corrosion in Kansas Production Operations 51	396	
Liljeberg, J. W. , see Ballou, J. K.			Piper, John D. , see Piper, Walter J.			Speller, F. N. Discussion—Aerobic Microbiological Corrosion of Water Pipes..... 51	109	
M			Piper, Walter J. Tower Footing Corrosion, with John D. Piper..... 51	134		Stacy, S. J. , see Mundt, H. W.		
Magee, G. M. Testing Inhibitors of Brine Drip-pings Corrosion of Railway Tracks and Equipment..... 51	186		Pogacar, C. F. Corrosion Problems in the Modern By-Products Coke Plant, with E. A. Tice..... 51	76		Stelzer, J. G. Discussion—Corrosion Problems in Rural Power Distribution..... 51	311	
Maitland, T. J. Discussion—Economics of Rectifier Installation For Cathodic Protection of a Bare Pipe Line..... 51	325		Promisel, N. E. Prevention of Corrosion in Naval Aircraft, Part I of Two Parts with G. S. Mustin..... 51	339		Stillman, N. , see Wachter, A.		
Matthews, J. W. Sodium Hydroxide as Inhibitor of Pitting in 18-8 Stainless Steel, with H. H. Uhlig..... 51	419		Promisel, N. E. Prevention of Corrosion in Naval Aircraft, Part II of Two Parts with G. S. Mustin..... 51	377		Straub, Frederick G. Prevention of Corrosion and Metal Attack in the Steam Water Cycle of the Steam Power Plant, with Harry D. Ongman..... 51	312	
Mears, R. B. Discussion—Halides as Acid Pickling Inhibitors, with J. M. Bialosky..... 51	74		R			Straumanis, M. E. The Corrosion of Titanium in Acids—The Rate of Dissolution in Sulfuric, Hydrochloric, Hydrobromic and Hydroiodic Acids, with P. C. Chen..... 51	229	
Mendizza, A. , see Compton, K. G.			Raymond, K. L. Corrosion Problems of Motor Coaches 51	303		Sudrabin, L. F. Discussion—Potential Measurements for Determining Cathodic Protection Requirements..... 51	417	
Miller, P. T. , see Rogers, Walter F.			Reichard, E. C. Discussion—The Use of Cathodic Protection in Conjunction with Paint Coatings 51	69		T		
Miller, R. F. , see Treseder, R. S.			Reichard, E. C. Discussion—Cathodic Protection of an Active Ship in Sea Water—Part II..... 51	405		Thompson, L. J. , see Mundt, H. W.		
Mitchell, F. K. Control of Corrosion Damage to Rolling Stock Through Proper Design and Maintenance..... 51	269		Renshaw, William G. Discussion—Materials of Construction for Handling Sulfuric Acid..... 51	317		Tice, E. A. Corrosion Problems in the Modern By-Product Coke Plant—Addendum 51	128	
Morris, F. M. , see Kirchner, O. E.			Renshaw, William G. Passivating Characteristics of the Stainless Steels, with J. A. Ferree 51	353		Tietze, I. B. Discussion—Internal and External Corrosion Experience in Shell's Products Pipe Lines..... 51	27	
Morrison, Barclay Discussion—Materials of Construction for Handling Sulfuric Acid..... 51	317		Renshaw, William G. Discussion—Sodium Hydroxide as Inhibitor of Pitting in 18-8 Stainless Steel..... 51	422		Tracy, A. W. Historic Church's Copper Roof Good After 213 Years..... 51	373	
Mundt, H. W. Report of Protective Coatings Investigation, Underwater Exposure Tests, 1941-1949 (Summary and Conclusions) with L. J. Thompson & S. J. Stacy..... 51	50		Riegel, Garland M. Discussion—Passivating Characteristics of the Stainless Steels..... 51	400		Treseder, R. S. Corrosion in the Ammonolysis of Aliphatic Chlorides, with R. F. Miller 51	225	
Murray, Christopher A. Thermoform Catalytic Cracking Gas Plant Corrosion Survey..... 51	98		Robinson, H. A. Discussion—Prevention of Corrosion in Naval Aircraft, Part II..... 51	389		U		
Mustin, G. S. , see Promisel, N. E.			Rogers, W. F. A Proposed Standard Method for Measuring the Electrical Resistance of Pipe Line Coatings, with B. H. Davis, Lyle Sheppard, L. G. Sharpe, E. R. Allen, Donald Bond, P. T. Miller..... 51	245		Uhlig, H. H. Discussion—The Passivating Characteristics of the Stainless Steels 51	400	
N			Roll, Kempton H. Discussion—Materials of Construction for Handling Sulfuric Acid..... 51	454		Also see Matthews, J. W.		
McFarland, Roland Discussion—High Pressure Sweet Oil Well Corrosion..... 51	318		Rush, E. H. , see Smith, S. S.			W		
McIntyre, G. H. Porcelain Enamel as a Corrosion Resistant Coating for Metals..... 51	118		S			Wachter, Aaron Objectives and Progress of Technical Practices Committee-9—Corrosion Inhibitors..... 51	145	
McPherson, John L. Discussion—Stress Corrosion Cracking in Alkaline Solutions..... 51	400		Scheil, M. A. TP-7 Plans Publication of Bulletin on Corrosion at Elevated Temperatures 51	179		Dicyclohexylammonium Nitrite, a Volatile Inhibitor for Corrosion Preventive Packaging, with T. Skel & N. Stillman..... 51	284	
Nathan, Charles C. Corrosion Inhibition in Gas Condensate Wells by Intermittent Injection of Alkaline Solutions..... 51	397		Scheil, M. A. Discussion—Materials of Construction for Handling Sulfuric Acid..... 51	317		Also see Dolg, Keith		
Niellwocki, L. M. Discussion—The Passivating Characteristics of the Stainless Steels 51	400		Schmidt, H. W. Stress Corrosion Cracking in Alkaline Solutions—TP-5C Sub-Surface Corrosion by Alkaline Solutions, A Technical Practices Committee Report, Pub. 51-3, with P. J. Gegner, G. Heine, E. A. Tice, C. F. Pogacar & E. H. Wyche 51	295		Waldrup, H. E. Discussion—Some Applications of Corrosion Inhibitors in the Petroleum Industry 51	316	
Noser, Walter F. Objectives and Progress of TP-2—Galvanic Anodes for Cathodic Protection 51	1		Schmidt, H. W. Discussion—The Passivating Characteristics of the Stainless Steels 51	400		Discussion—Control of Sour Crude Corrosion in Kansas Production Operations 51	396	
O			Schwerdtfeger, W. J. Discussion—Potential Measurements for Determining Cathodic Protection Requirements..... 51	418		Whitwham, D. Corrosion Fatigue—The Influence of Disarrayed Metal, with U. R. Evans 51	28	
Offermann, P. F. , see Ballou, J. K.			Seymour, Raymond B. The Chemical Resistance of Phenolic Resins..... 51	151		Williams, E. J. , see Kehn, G. R.		
Ongman, Harry D. , see Straub, Frederick G.			Sharpe, R. D. , see Rogers, Walter F.			Williams, R. D. , see Dix, E. H.		
Osborn, Oliver Combating Corrosion in a Chemical Plant With Magnesium Anodes 51	2		Shenard, Spencer W. Materials of Construction of Handling Sulfuric Acid, NACE Technical Practices Committee Report—TP-5A Materials, Handling and Manufacturing Sulfuric Acid 51	279		Williamson, M. A. Technical Practices Committee-15—Corrosion Control in the Transportation Industry 51	113	
Oxford, W. F., Jr. Discussion—Some Applications of Corrosion Inhibitors in the Petroleum Industry 51	316		Sheppard, Lyle Discussion—Economics of Rectifier Installation for Cathodic Protection of a Bare Pipe Line..... 51	326		Winn, Harry M. , see Bried, Edward A.		
Discussion—High Pressure Sweet Oil Well Corrosion..... 51	318		Also see Rogers, W. F.			Wise, R. S. Discussion—Bacterial Casing Corrosion in the Ventura Field..... 51	319	
P			Shields, James E. Discussion—Dicyclohexylammonium Nitrite, a Volatile Inhibitor for Corrosion Preventive Packaging..... 51	404		Works, G. A., Jr. Discussion—The Use of Cathodic Protection in Conjunction With Paint Coatings 51	209	
Palmer, W. G. Corrosion Inhibitors for Steel..... 51	10					Wyche, E. H. , see Schmidt, H. W.		
Parker, Ivy M. The Literature of Corrosion..... 51	450					Discussion—Corrosion Resistant Equipment for the Corn Refining Industry..... 51	133	

CORROSION ABSTRACTS

As Published in

CORROSION

Volume 7-1951

Official Publication

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

919 Milam Building, Houston 2, Texas

COPYRIGHTED, 1951

PAGE NUMBERS BY MONTHS

Pages

1a- 30a	January
31a- 36a	February
37a- 56a	March
57a- 74a	April
75a- 96a	May
97a-116a	June

Pages

117a-144a	July
147a-184a	August
185a-208a	September
209a-222a	October
223a-244a	November
245a-266a	December



INDEX TO CORROSION ABSTRACTS, VOLUME 7, 1951

This table lists numbers printed in lower outer margins of abstract section. The affix "a" has been dropped. Classification 1.8 Fundamentals of the November, 1950, index has been distributed in 3. Characteristic Corrosion Phenomena. Used here are the first two

places of the June, 1951, Revision of the NACE Abstract Filing Index which is printed in full in *Corrosion*, December, 1951, as part of the Index to Technical Material in Volume 7.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
1 GENERAL													
1. Miscellaneous			37			97			185				1
2. Importance						97			186			245	2
3. Reviews			37						186				3
4. Bibliographies									186				4
5. Directories of Material									186			246	5
6. Books		1	37						186			246	6
7. Organized Studies of Corrosion			38			97			188			246	7
8. Personalities and Directories of Individuals													8
2 TESTING													
1. General				57			117		189			246	1
2. On Location Tests							117	147	190			246	2
3. Laboratory Methods and Tests		31		57		98	118		190		223	246	3
4. Instrumentation				60		98	119		200			251	4
5. Specifications and Standardization							120		202				5
6. Preparation and Cleaning of Specimens													6
7. Other													7
3 CHARACTERISTIC PHENOMENA													
1. General													1
2. Forms		2	39	571	75	97	120	147	202	209	223		2
3. Biological Effects				62	75		120	147		210			3
4. Chemical Effects				62						212			4
5. Physical and Mechanical Effects			31	62			120			212	224		5
6. Electrochemical Effects		2		64			1172			218	226	252	6
7. Metallurgical Effects		2		64						220	226	252	7
8. Miscellaneous Principles						93			189				8
9. Other													9
4 CORROSIVE ENVIRONMENTS													
1. General													1
2. Atmospheric		2			78			148	204				2
3. Chemicals, Inorganic		2		66			122		204		230		3
4. Chemicals, Organic		4		66			122	143			230		4
5. Soil		4		66			122	148			232		5
6. Water and Steam		4		66			122	149			232	254	6
7. Molten Metals													
8. Other													8
5 PREVENTIVE MEASURES													
General		5							143				1
2. Cathodic Protection		5		68			124	148		236			2
3. Metallic Coatings		6		68	78		126	152		236			3
4. Non-metallic Coatings and Paints		12	31	40	70		93	134	155	204	240	256	4
5. Oil and Grease Coatings									166				5
6. Packaging		18				99			167			260	6
7. Treatment of Medium				72					167			260	7
8. Inhibitors and Passivators		16		72					167		242		8
9. Surface Treatment		18	32	42		80	99		170			260	9
10. Other					84				206				10
6 MATERIALS OF CONSTRUCTION													
1. General									206				1
2. Ferrous Metals and Alloys		20			84	100		176			242		2
3. Non-ferrous Metals and Alloys—Heavy		20		46	86	100		178			242		3
4. Non-ferrous Metals and Alloys—Light				48	88	102		180			243	260	4
5. Metals—Multiple or Combined Discussion						102			206			263	5
6. Non-Metallic Materials		21		50		92	102		207			263	6
7. Duplex Materials		22										264	7
8. Other													8
7 EQUIPMENT													
1. Engines, Bearings, and Turbines		22		52		92	104					264	1
2. Valves, Pipes, and Meters				52		92							2
3. Pumps, Compressors, Propellers, and Impellers				52		92							3
4. Heat Exchangers		24		52		92	104						4
5. Containers		24					104						5
6. Unit Process Equipment							106						6
7. Electrical Telephone and Radio		26					106						7
8. Wires and Cables (non-electrical)		26											8
9. Specifications													9
10. Other		26		52			106						10
8 INDUSTRIES^a													
1. Group 1		26				93							1
2. Group 2				52			106	134					2
3. Group 3				54			106	134					3
4. Group 4				54	73	93	109	134					4
5. Group 5		28					110	139					5
6. Group 6							110	140					6
7. Group 7													7
8. Group 8							110	140					8
9. Group 9		28				95	112	142					9
10. Group 10		29					143						10
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	

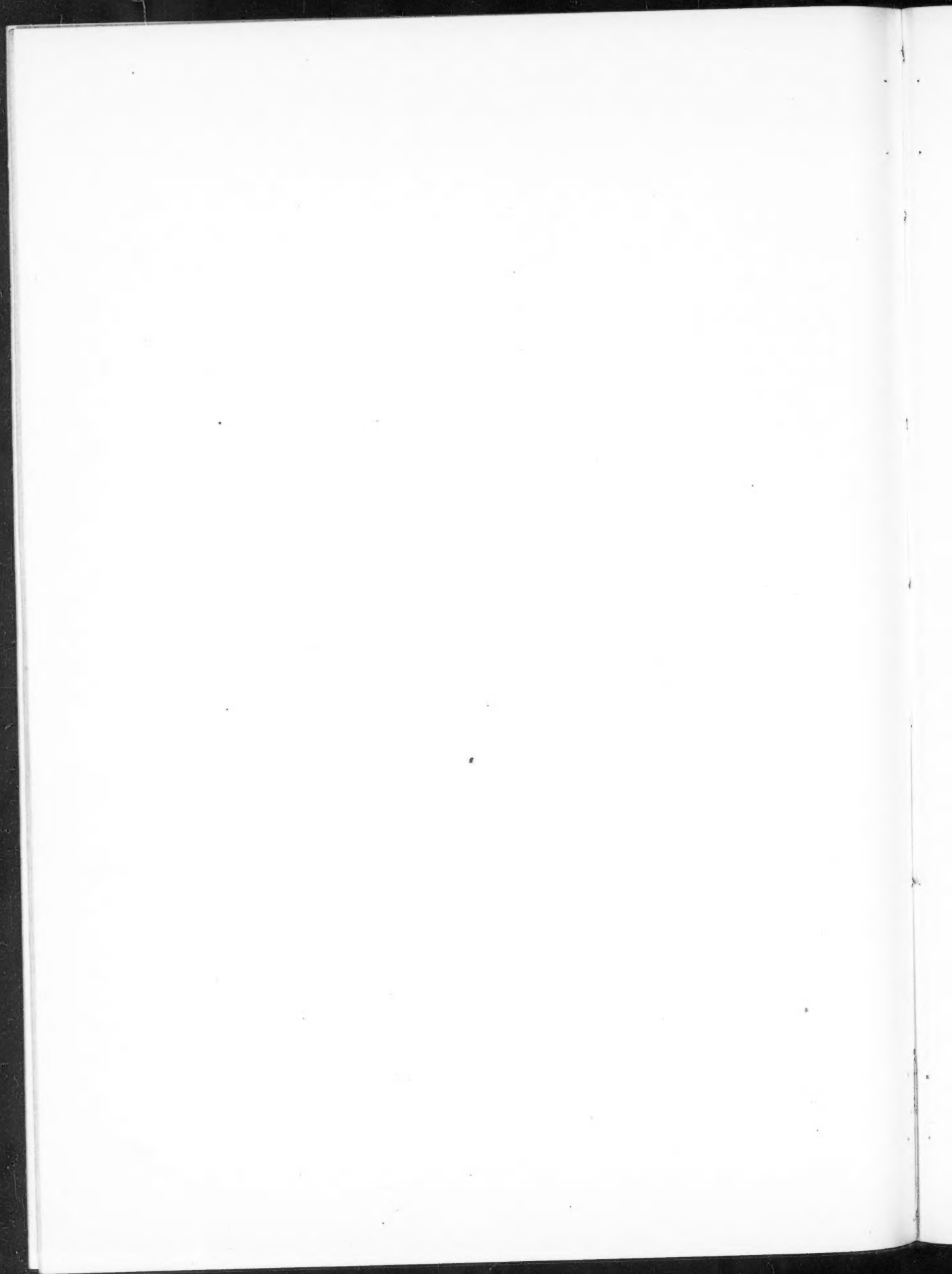
- See also Page 62.
- See also Page 121.
- List of Industries.

1. Air conditioning, architecture and building, refrigeration, sewage and water.

- Communications, power.
- Agriculture, beverage, dairy, fermentation, food, sugar, starch.
- Fuel, gases, petroleum refining and production, rubber.

- Ceramics, glass, pulp and paper, wood products.
- Laundry, soap and detergents, textiles.
- Graphic arts, instruments, jewelry, photography.
- Chemical manufacturing, dis-

- tilled liquor, electroplating, leather, tanning, metal fabrication, pharmaceuticals.
- Aircraft, automotive, pipe line, railroad, shipping.
- Explosives, metallurgy, mining, ordnance, war materials, other.



ERRATA—Corrosion—Vol. 6 and 7

(These corrections are printed in conformity with the American Standards Association recommendations for the publication of errata in such a way they may be clipped from this page (which is blank on the reverse side) and pasted over the areas in which the errors appear.)

●
Recommended Practices for Surface Preparation of Steel. TP-6G Surface Preparation for Organic Coatings. *Corrosion*, 6, No. 8, 276-282 (1950) August. Page 281, Col. 1, Line 20. Change to read

2) The increase in durable life of the organic finish.

Changing "decrease" to "increase."

(Note: Reprinted copies of this article also require correction.)

●
Five Year Index to Technical Articles. *Corrosion*, 6, No. 12 (1950) Dec.

Page 11. May - Vol. 5 - No. 5. Topic of the Month—Corrosion in Sour Crude Storage Tanks—By Derk Holstein. 168.

Delete check mark at 8.5.

Insert check mark at 8.4.

●
Cathodic Protection Technical Practices. Bulletin III.

Correlating Committee on Cathodic Protection
Corrosion, 7, No. 6, 202-209 (1951) June.

Page 208, Appendix B, Reference No. 39, Line 3:
Change to read:

Corrosion, 3, 539 (1947).

Changing page number from 359 to 539.

●
A Proposed Standard Method for Measuring the Electrical Resistance of Pipe Line Coatings. By Walter F. Rogers, B. H. Davis, Lyle Sheppard, L. G. Sharpe, E. R. Allen, Donald Bond and P. T. Miller. *Corrosion*, 7, No. 7, 245-251 (1951).

Substitute the equation below for the equation printed on Page 246, Column 2, immediately below Line 13:

$$K = \left(V - \frac{I\rho}{2\pi L} \ln \frac{r_2}{r_1} \right) \frac{L}{I}$$

The correction being that the ratio $\frac{L}{I}$ is substituted for the ratio $\frac{1}{N}$.

●
Corrosion Inhibition in Gas Condensate Wells By Intermittent Injection of Alkaline Solutions.

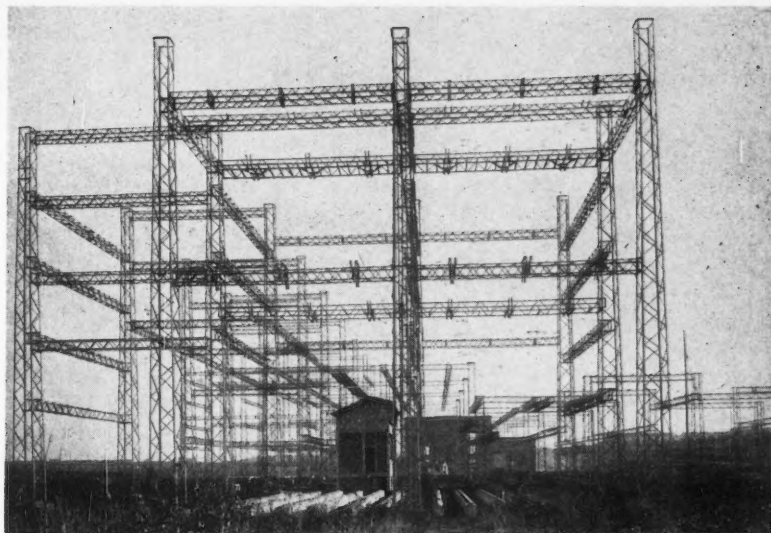
By Charles C. Nathan. *Corrosion*, 7, No. 11, 397-399 (1951) November.

Acknowledgment

The author wishes to acknowledge the cooperation of The Texas Company in the gathering of the data in this paper and in granting permission for its publication. Thanks are also due his colleagues, G. J. W. Murphy and L. M. Hubby, who aided materially in this work.

Topic of the Month

Figure 2—An open transformer station near Basel, Switzerland, which has been zinc-coated by the Electro-Pistole.



Versatile Electric Arc Metal Spraying Pistol Has High Potential

UP TO 50 pounds of metal per hour can be sprayed with the Schoop-Pistole* and temperatures up to 4000 degrees C are reported at the melting arc, sufficient to fuse and disperse such hard metals as molybdenum, chromium, tungsten and their alloys

* Invented by M. U. Schoop, Gladsbach Strasse, Zurich 5, Schweiz.

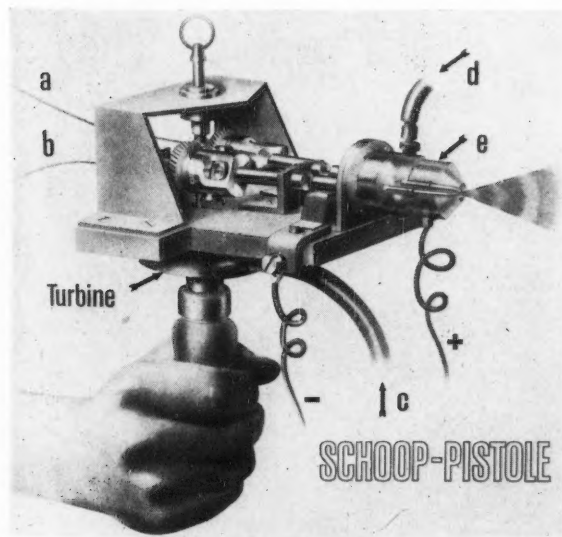


Figure 1—Operation of the Schoop-Pistole. a-b—The wires which form the electrodes. c—Compressed air tube leading to the 35,000 rpm turbine which operates the feed mechanism advancing the wires into the arc. d—Compressed air tube supplying air to the jet which disperses the molten metal in the arc. (In later models only one compressed air tube is used.) e—Control or cut-off valve or cap.

and apply them to the desired surfaces. Temperatures of the particles emitted from the arc are so high they will fuse into a glass or quartz surface forming a homogeneous, even metal film impossible to separate physically from the underlying material.

The inventor claims three times more by weight of zinc and aluminum may be deposited than with the gas-fired spray pistol.

In coating iron or steel a nitrated zone is reported at the interface of the body and coating material.

The pistol consists essentially of two wires (electrodes), the necessary electrical connections and an air jet, which blows through the arc created by the electrodes. (See Figure 1 for details.) The wires are fed by action of a 35,000 rpm turbine actuated by the air before impinging on the arc.

Only 50 Volts Used

In the electric pistol two wires of small transverse section are fed into contact at the point of the pistol. A 50-volt direct current is applied across the wires, the resulting short circuit melting the contact metal. A jet of air (four atmospheres) is directed at the arc, driving the molten material away and reducing it to very small particles. When contact is broken an arc is formed in which further fusion takes place. Tests with a rotating mirror show a recurring short-circuit also plays a role in the melting of the electrodes.

An investigative report by Prof. G. Korda (Paris) says in part: Since the arc is very short and (an air) stream of considerable strength passes through it, the inner arc is also strongly ionized and filled

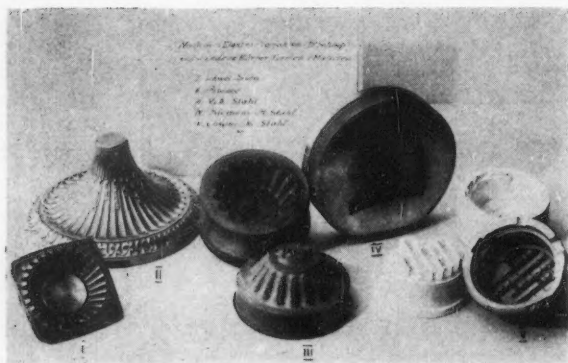


Figure 3—Forms and molds of hard metals. Item I, Swedish steel. Item II, bronze. Item III, 4A Steel. Item IV, Siemens M-steel. Item V, chrome nickel-steel.

with a dense metallic dust. Because of the small transverse section of the electrodes the arc cannot deviate.

Other Uses Given

Besides the obvious application of cathodic metals to steel (See Figure 2) the Electro-Pistole has been used to create dies for forming elastomer or ceramic parts by spraying on a pattern. (Examples of this kind of application are shown in Figure 3) Item II

in this figure is a pedestal coated with bronze. Bronze coatings can be deposited, the inventor states, by using one electrode of copper and one of zinc. Other composite coatings also can be deposited.

The gun may be used also to spray metals onto textiles, where the metal particles penetrate the material and result in a product which is pliable, porous to air and which still partakes in large measure of the protective characteristics of the metal used. This process will produce fabrics impregnated to protect workers against damaging rays, heat and other destructive forces. The gun also has been used to coat with metals celluloid, paper and other combustible materials.

Discovered by Accident

Dr. Schoop says the idea for the electric pistol developed accidentally when he saw lead bullets fired from a target rifle by his children plate themselves on a garden wall in Garenne-Columbes, near Paris, where the family lived at the time.

Use of the electric pistol has progressed slowly for two apparent reasons, the inventor says. One, the higher initial cost of the equipment (three times that of the gas pistol) and the idea there is danger from the electric current. Dr. Schoop states that at 50 volts (the current used) there is no danger from either direct or alternating current.



NACE News

Teche Section Files Petition for Recognition

Pittsburgh Arranges 8-Months' Schedule

The eight most popular subjects among 19 submitted for consideration as program topics to Pittsburgh Section members have been scheduled for monthly meetings ending with May 1952. Because the option of combining two subjects was given, members elected to have combinations on two occasions.

The following schedule has been arranged for the section:

October 4—Causes of Localized Corrosion, R. B. Mears, U. S. Steel Company.

November 1—Recent Developments in Synthetic Resin Coatings, J. P. Garvey, Research Department, Pittsburgh Plate Glass Co.

December 6—Chemical Treatments of Surfaces for Protective Coatings, Harold Rosenbloom, Thompson & Co.

January 3—Stress Corrosion, E. H. Dix, Jr., Aluminum Co. of America.

February 7—Corrosion Problems in Industry, speaker to be announced.

March 6—Bacteriological Corrosion, Speaker to be announced.

April 3—Evaluation of Tapes as Protective Coatings, Carl Johnson, Minnesota Mining & Mfg. Co.

May 1—Corrosion of Underground Structures by Stray Currents, Norman Peifer, Manufacturers Light & Heat Co.

Fontana Will Speak At Philadelphia Meeting

A Christmas program and an address by Mars G. Fontana of Ohio State University are planned for the quarterly meeting of Philadelphia Section December 14. Dr. Fontana will speak on "Corrosion and Its Prevention."

The meeting, to be held at the Poor Richard Club, 1319 Locust St., Philadelphia, will include dinner at 6:30 p.m.

Logan Accepts Post

Kirk H. Logan, with the Cast Iron Pipe Institute, Washington, D. C., has accepted chairmanship of the Pipe Line and Underground Corrosion Round Table to be held at Galveston during the 1952 annual meeting March 10-14.

NACE encourages the formation of college and university groups interested in corrosion by offering a special rate to students. School section formations also are encouraged.

**Corrosion
News Deadline:
10th of Month
PRECEDING
Date of Issue**

Five Months' Program For Chicago Given

Five consecutive months' programs have been outlined for Chicago Section. Two pertain to pipe lines, one to welding corrosion problems, one to inhibitors and one meeting will be a round table discussion of general corrosion.

The meetings will be as follows:

January 20—R. A. Huseby, Metallurgical Engineer, A. O. Smith Corp., "Factors Influencing Corrosion of Mild Steel and Mild Steel Welds in Process Equipment."

February 19—D. C. Glass, Pipe Line Department, The Pure Oil Company, "Cathodic Protection and Common Sense," in which cathodic protection will be discussed in down-to-earth terms.

March 18—F. W. Pfohl of Armour Research Foundation, has been tentatively scheduled to present "The Mechanism of Corrosion Inhibition by Polar Organic Compounds."

April 15—Aaron Rabinkoff, Products Pipe Line Department, Standard Oil Company, will speak on the solution of internal corrosion of pipe lines of finished petroleum products by dehydration.

May 20—Round Table Discussion by a panel of members and guests on general corrosion problems.

Dr. H. T. Francis of Armour Research Foundation was speaker at the October 16 meeting, presenting a paper on "Detecting Corrosion Currents in Action." J. P. Oliver of National Carbon Division, Union Carbide and Carbon Corp., addressed the section November 20 on the application of cathodic protection to industrial, water, food processing and marine installations. No meeting is scheduled for December.

Pittsburgh Section

Joseph P. Garvey of Pittsburgh Plate Glass Company, Research Department, Springdale, Pa., spoke to Pittsburgh Section at an evening meeting November 1 on "Recent Developments in Synthetic Resin Coatings." The meeting was held in the Conference Room, Mellon Institute, Pittsburgh, beginning at 8:15 p.m.

A petition has been filed for recognition of the Teche Section, to serve NACE members in the vicinity of Lafayette, La. Temporary officers were appointed at a meeting November 14 at Lafayette attended by 26 persons of whom three were members. Sufficient applications for membership were submitted to assure section status.

Temporary officers named were C. L. Garner, Tube-Kote, Inc., chairman; Gus Vogler, Dowell, Inc., vice-chairman; R. W. Schutt, Shell Oil Company, secretary. A committee was named to determine what the regular meeting day will be.

The area requested by the section is bounded on the north and east by Bayou Teche, on the south by the Gulf of Mexico and on the west by the confines of the Sabine-Neches Section.

The section will meet December 10 to hear H. E. Waldrup of Houston.

Present from Houston were T. F. P. Kelly, South Central Region director and A. B. Campbell, executive secretary.

Heavy Corrosion Loss Cited at Urbana Meet

H. H. Uhlig, speaking at a session on the chemistry of water treatment at University of Illinois during dedication of the new \$490,000 laboratory and office building of the Illinois State Water Survey Division, said "Corrosion of metal equipment costs this country not only billions of dollars for replacing damaged equipment, but also expends human effort and dissipates dwindling supplies of metals." He also covered economic losses from corrosion of other industrial plant equipment.

A three day conference on water resources was featured in addition to the dedication ceremony.

"Modern boiler treatment," he said, "by reducing corrosion has made low cost power a reality but much still remains to be done."

Navigational Structures Costly

"Operation of canal gates provides another illustrative example," Dr. Uhlig asserted. "It costs over \$200,000 to replace a corroded gate at the Panama Canal, with additional losses resulting from shut-down and delays made necessary by repairs. A major portion of these losses are now avoided by the application of so-called cathodic protection. The initial cost of applying cathodic protection is less than one-half of one percent of the cost of the gates and it is no longer necessary to paint them so often."

W. H. Rodebush, professor of physical chemistry at the University of Illinois, spoke on "Composition of Water

(Continued on Page 4)

Sabine-Neches Section Plans Six Meetings

A six months' schedule of programs for meetings of Sabine-Neches Section has been announced as follows:

December 6—W. Z. Friend, The International Nickel Co., Inc., New York. At Beaumont, location not determined. J. T. Dwyer, Gulf Oil Corp., chairman.

January 30—John Cook, chief inspector, Humble Oil and Refining Co., Baytown Refinery, "Graphitization of Steel at High Temperatures." Holland Hotel, Orange, Texas. D. L. Burns, Gulf Oil Corp., chairman.

February 27—W. B. Cook, Gulf Oil Corp., "Refinery Painting." Lake Charles, La., location not determined.

Lewis M. Nieliwocki, E. I. DuPont de Nemours & Co., Inc., chairman.

March 27—Panel Discussion. Port Arthur, location not determined. Lewis M. Nieliwocki, chairman.

April 26—Field Trip, Magnolia Petroleum Refinery, Beaumont, Texas. C. A. Ridenour, Magnolia Petroleum Co., chairman tentatively.

May—Social meeting. Orange, Texas, location undetermined. W. F. Oxford, Sun Oil Company, chairman.

An index covering all technical material published in Corrosion for the years 1945-50 inclusive was published in the December 1950 issue. Copies of the issue are available. The indices may be extracted and used separately if desired.

Water Treatment Topic Discussed by C. M. Brown

Sabine-Neches Section heard C. M. Brown of W. H. & L. D. Betz Company speak on "Water Treatment of Recirculating Cooling Water Systems," at Holland Hotel, Orange, Texas, October 30. Twenty-eight members and eight guests were present. The talk covered water treatment by chromates, phosphates and the Dianodic system with field data from widely scattered plants illustrating results.

Bert Cook, section chairman, and R. B. Clarke, trustee, reported on the South Central Regional Meeting at Corpus Christi.

North Texas Section Hears Ellis D. Verink

"Use of Aluminum in the Petroleum and Petrochemical Industries," was the topic of an address by Ellis D. Verink, Jr., of Aluminum Company of America, New Kensington, Pa., to members of North Texas Section November 5. The dinner meeting was held at Venus Restaurant, Dallas.

The joint meeting with ASM North Texas Section was attended by 30 members and 36 guests.

The nominating committee reported renomination of current officers for 1952, and an election was scheduled for December 3.

Regular meetings of the section are held first Mondays monthly.

Unclassified Technical Data May Be Exported

Publications containing unclassified technical information freely available in the United States may be sent overseas under general license except to North Korea, the Office of International Trade, U. S. Department of Commerce, has ruled.

Qualifications for export under general license are: the publication must be sold at newstands or bookstores, available by subscription or purchase to any person without restriction, approved for second class mailing or freely available at public libraries.

Huge Corrosion—

(Continued from Page 3)

Substance," stressing the value of cooperative research by the university chemistry department and the water survey division. From this cooperation has come the use of infra-red analysis, now a very important tool of the organic chemist and being used also by biochemists in protein studies.

"Another important development of this cooperative work," Prof. Rodebush said, "is knowledge about the structure of water inside living organisms."

This water, he asserted, is important in the frost resistance of wheat and corn.

The research also has been fruitful in explaining the solubility of non-polar compounds in water and suggests explanations of previously unexplained factors affecting the flow of water in pipes and channels.


THE PIG WITH THE POKE

CLEANS PIPE LINES

5000 PIPE LINE CASINGS

INSTALLED IN 1950 WITH THESE

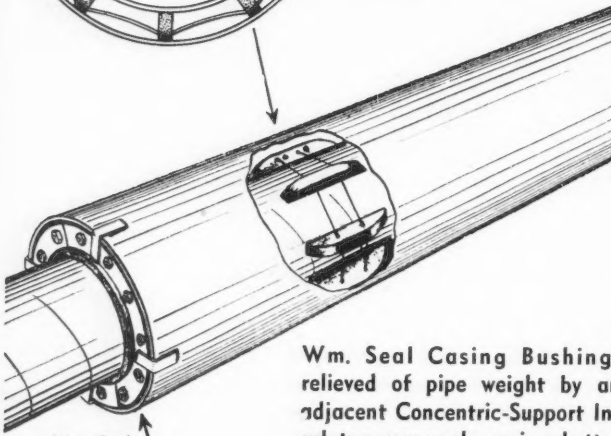
WILLIAMSON PRODUCTS



PIPE
CENTERED
IN CASING

Improved "Concentric-Support" Insulators* now have 50 to 60% more Support Blocks.

Utilize high voltage of welding machine for positive proof of pipe to casing insulation.



Wm. Seal Casing Bushing

Wm. Seal Casing Bushings relieved of pipe weight by an adjacent Concentric-Support Insulator now seals casing better than ever before.

Write for NEW 1951 Installation Booklet, 149-A

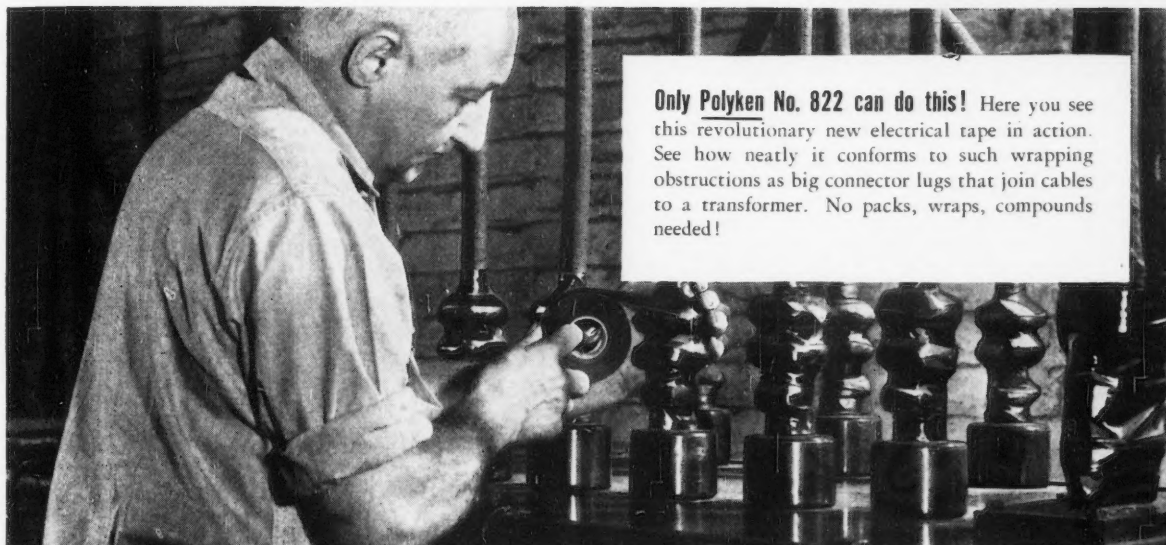
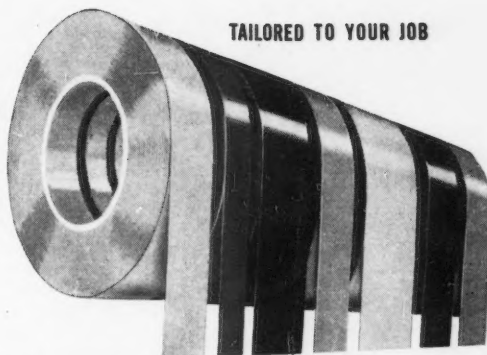
*Patents Pending

T. D. Williamson, Inc.

TULSA 9, OKLAHOMA

THE NEW Polyken® INDUSTRIAL TAPES

TAILORED TO YOUR JOB



Only Polyken No. 822 can do this! Here you see this revolutionary new electrical tape in action. See how neatly it conforms to such wrapping obstructions as big connector lugs that join cables to a transformer. No packs, wraps, compounds needed!

Costs CUT IN HALF with new Tape

Until *Polyken* No. 822 was developed, wrapping high-tension cables was a two-step job. First, a rubber splicing compound, followed by an outer wrap of friction tape.

Now you can forget about the rubber compound! *Polyken* Electrical Tape No. 822 is only 9 mils thick—but it's 10,000 volts strong (dielectric strength). Makes *one* quick operation out of two tedious ones with no sacrifice of efficiency.

No. 822 is the only oriented polyethylene tape with a successful pressure-sensitive adhesive. Stretches both ways, so that it covers rough and irregular surfaces. High moisture resistance. Solvent proof. Corrosion proof.

For splicing, wrapping, insulating, corrosion coating of cables, wires, controls, pipes, conduits, and hundreds of other uses. Write for free samples today!

Polyken, Dept. CM, 222 West Adams St., Chicago 6, Ill.

For specifications and further information on this and other Polyken tapes, please send me your **FREE BOOKLET**, "Tape is a Tool."

Name _____ Title _____
Company _____
Street Address _____
City _____ Zone _____ State _____

Polyken Industrial Tape, Department of Bauer & Black, Division of The Kendall Company

RUBBER LININGS

to resist

CORROSION



WHEN your problem involves the processing, storing or transportation of corrosive acids and chemicals, you can depend on Acme-Fisher to furnish the correct protective rubber lining.

Every Acme-Fisher installation is specially formulated to provide the highest degree of resistance to corrosion and abrasion. It is permanently bonded to the metal surface and will not loosen with contraction and expansion of metal.

A MATERIAL FOR YOUR JOB

A wide variety of materials and many formulations of each, plus the technical men to make an analysis for your operation.

LAYBOND, Soft Rubber
LAYBOND, Semi-Hard Rubber
LAYBOND, Hard Rubber
TRI-BOND, (Multiple Hardnesses)
NEOBOND, (Neoprene)
POLYVINYL
SARAN RUBBER*
NARAS RUBBER
PHENOLIC, Baked

*Trade Mark, Dow Chemical Co.

2 PLANTS

Acme-Fisher of Texas
Houston 20, Texas
Broadway Rubber Corp.
Louisville 2, Ky.

Field crews operate from both plants.

Address inquiries to Dept. 107

Acme-Fisher Division

BROADWAY
RUBBER CORPORATION

Louisville 2, Kentucky

Two Short Courses Are Scheduled, Another Is Tentatively Planned

Short courses on corrosion scheduled during 1952 in which NACE will co-operate have been listed as follows by Norman Hackerman, chairman of the education committee:

February 4-9, University of California, Los Angeles.

September 8-12, Washington University, St. Louis.

There also has been tentatively scheduled a short course at University of California, Berkeley.

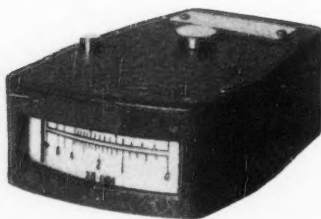
The University of Delaware is giving a semester-long credit course in corrosion theories and prevention in the spring of 1952. NACE will not participate in this course which is patterned after that given at Stevens Institute.

Hydrogen Attack on Steel Is W. A. Bonner's Topic at St. Louis

W. A. Bonner, corrosion engineer for Shell Oil Co., Wood River, Ill. spoke to Greater St. Louis Section's October 15 meeting on "Hydrogen Attack on Steel in Refinery Equipment." The illustrated lecture's main points were the causes, manifestations and methods of preventing hydrogen attack on steel.

The September 17 meeting was primarily a social and business meeting. Non-technical sound and color motion pictures were shown.

Measure Thickness of Mastic Coatings in Seconds!



ELCOMETER THICKNESS GAUGE

Permits measurement of any non-magnetic protective coating on magnetic surfaces with accuracy of $\pm .0001$ -inch.

SIZE: 2" x 3 1/2"

WEIGHT: 6 Ounces

Write Dept. C for Leaflet, Details

GARDNER
LABORATORY, INC.

Bethesda, Md.

San Francisco Bay Area Section Hears LaQue

F. L. LaQue of The International Nickel Co., Inc., spoke to members of San Francisco Bay Area Section October 31 at a dinner meeting on "Corrosion Testing and Engineering." The meeting was held at the Engineers' Club, San Francisco. It was a joint meeting with the Northern California District ASTM.

Corrosion Short Course Scheduled at UCLA

A six-day Short Course in Corrosion sponsored by the National Association of Corrosion Engineers has been scheduled by the Department of Engineering, University of California at Los Angeles. The course will be held February 4-9, 1952, inclusive.

Topics on the instruction program, to be taught by lecturers from industry and academic institutions will be: Fundamentals, Materials of Construction, Environment, Protective Coatings, Cathodic Protection, Chemical Treatment and Specific Industrial Applications.

The instruction will be given at 104 Franz Hall, University of California at Los Angeles. The fee, which covers a copy of the transactions, will be \$35.

Housing may be arranged on an individual basis. Information may be had from Engineering Extension, University of California, Los Angeles 24, Calif.

E. D. Verink Addresses Houston Section Nov. 6

Ellis D. Verink, Jr. of Aluminum Company of America addressed 44 NACE members and guests and nearly a hundred members of the Texas Chapter American Society for Metals November 6. The joint dinner meeting was held at Ben Milam Hotel, Houston.

Mr. Verink's talk, "Aluminum in the Petrochemical Industry," covered alloying of aluminum for corrosive environments in the chemical and petroleum industry. The advantages and limitations of aluminum and its alloys were explained.

Clad aluminum materials consisting of a body with good mechanical characteristics covered with an anodic protective layer have been used widely and offer promise of good service in corrosive applications, Mr. Verink said. Economics are of prime importance in materials selection, and present availability frequently is more important than any other consideration, Mr. Verink asserted.



J. E. Loeffler, left, program chairman, the speaker Ellis D. Verink, Jr., South Central Region Director T. F. P. Kelly and Charles G. Gribble, Jr., section vice-chairman, are shown enjoying a joke during the session.

Twelve Papers Related To Corrosion Presented At Metals Congress

The National Metal Exposition, National Metal Congress and World Metallurgical Congress were held in Detroit October 13-19. Technical programs were sponsored by American Society for Metals, American Welding Society, Special Libraries Association (Metals Division), Society for Non-Destructive Testing and American Institute of Mining and Metallurgical Engineers.

The following papers were of interest to corrosion engineers:

1. Metallic High-Temperature Resistant Alloys—a Comparison Between Fe-Cr-Al and Ni-Cr Alloys, by Gosta Hildebrand, Director of Research, Bultkoncernen, Hallstahammar, Sweden.
2. Season Cracking of Manganese Brass Propellers, by Hoshio Kaneda, Hiroshima Shipyard and Engine Works, West Japan Heavy Industries, Ltd., Hiroshima, Japan.
3. Anti-Corrosive Treatments for Magnesium, by Tukasa Kawamura, Assistant Chief of Manufacturing, Nikko Copper Works, Furakawa Electric Co., Nikko, Japan.
4. Development of Fused Metallized Coatings, by Harrison S. Sayre, U. S. Naval Engineering Experiment Station.
5. Nitric Acid Corrosion Data of Welded Stainless Steels, by M. A. Scheil and H. F. Ebling, A. O. Smith Corp.
6. The Metallizing Process, by F. J. Keller, Aluminum Research Laboratories, Aluminum Co. of America.
7. Modern Developments in Metallizing, by Sam Tour, Sam Tour and Co.
8. Today's Metallizing Applications, by K. B. Smith, Dix Engineering Co.
9. Oxidation of Titanium, by M. H. Davies and C. E. Birchenall, Carnegie Institute of Technology.
10. High-Temperature Oxidation of Copper-Palladium and Copper-Platinum Alloys, by D. E. Thomas, Westinghouse Electric Corp.
11. Mechanism and Kinetics of the Scaling of Iron, by M. H. Davies, M. T. Simnad, and C. E. Birchenall, Carnegie Institute of Technology.
12. The Literature on Corrosion, by I. M. Parker, Plantation Pipe Line Co., and Editor of *Corrosion*.

Many foreign visitors were present. Papers were presented by men from Australia, Belgium, England, France, Germany, Holland, India Italy Japan and Sweden.

Some 375 exhibitors displayed their products in five buildings at the Michigan State Fairgrounds. Express bus service was supplied from downtown hotels.

Third Shipment of Abstract Cards Mailed

The third shipment of abstract punch cards was mailed early in November to subscribers to the punch card service. The association contemplates shipments under the current subscription through March of 1952. There were 87 subscribers to the service at the end of October. A twice-monthly schedule of mailings to complete the 1951 schedule is contemplated.

Secret Ballots on NACE Election Due Dec. 29

To be counted, secret mail ballots for 1952 officers of NACE must be returned to Central Office NACE before December 29. A. B. Campbell, executive secretary urged members to return their ballots as quickly as possible so the tellers' work may be expedited. Ballots will be canvassed by a group of tellers after December 29 and the results of the election communicated to President N. E. Berry before January 10.

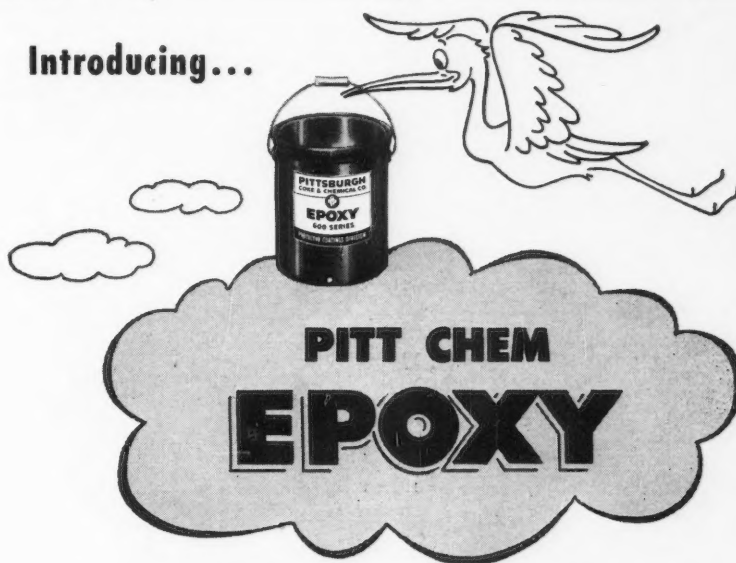
Under this schedule it is expected results of the election will be known in time for publication in the February issue of *CORROSION*.

Members were advised of the report of the nominating committee by mail September 7. No petitions having been received before October 15 for the addition of other names to the ballot the letter ballots were prepared and mailed by the executive secretary.

Nominees on the ballot are: For president, M. G. Fontana; for vice-president, Walter F. Rogers, for treasurer, R. A. Brannon; for director representing active membership, Norman Hackerman; for directors representing corporate membership, H. P. Godard and V. V. Kendall.

There is provision on the ballot for write-in candidates, but such a candidate must secure a plurality of votes over the other nominee to be elected.

Introducing...



A New Protective Coatings Series for Elevated Working Temperatures

The new Pitt Chem 600 Series of baked Epoxy Coatings provides you with an improved and specialized weapon for combating industrial corrosion. Effective for many applications involving elevated temperatures, Pitt Chem Epoxy Coatings offer these important advantages:

✓ Excellent Flexibility

✓ Outstanding Alkali Resistance

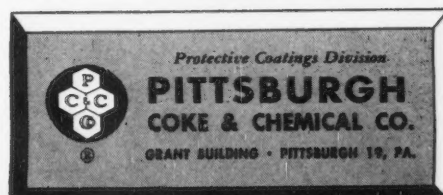
✓ Toughness—High Mar Resistance

✓ Good General Chemical Resistance

Send for Additional Information on PITT CHEM EPOXY Today!

- ★ Hot Applied Tar Base Coatings
- ★ Cold Applied Tar Base Coatings
- ★ Alkyd Coatings
- ★ Chlorinated Rubber Coatings
- ★ Vinyl Coatings
- ★ Phenolic Coatings
- ★ Epoxy Coatings

WAO 3025



COAL CHEMICALS • AGRICULTURAL CHEMICALS • PROTECTIVE COATINGS • PLASTICIZERS • ACTIVATED CARBON • COKE • CEMENT • PIG IRON

PLASTIC COATINGS

Vinyl and phenolic coatings, flame sprayed polyethylene and special cement linings, for protection against corrosion and/or contamination. Applications made in our plant or in the field to processing, storage and transportation equipment for oil, food, water, chemical and allied industries.

Other Metalweld services include Rubber and Koroseal lining, Metallizing, Sand Blasting and Welding. Inquiries are invited. Write for Bulletin (A).

Metalweld INC.

26th & HUNTING PARK AVE.
PHILADELPHIA 29, PA.



Casting-Welding Practice Manual Is Published

Steel Founders' Society of America has published a manual on casting-welding practice, "Recommended Practice for the Welding in Steel Castings." The 40-page booklet comprises a valuable file of practical welding data which previously has been unavailable in any single source reference, the society states. Copies may be obtained from F. Kermit Donaldson, executive vice-president, Steel Founders' Society of America, 920 Midland Bldg., Cleveland 15, Ohio. The price is 35 cents a copy.

Achema-X Meeting Set at Frankfurt

The Achema-X Exhibition Meeting for Chemical Engineering will be held at Frankfurt on Main May 18-25, 1952. A meeting of European engineering chemistry will be held and at the same time Societe de Chimie Industrielle, Paris, will hold its 25th International Congress for Industrial Chemistry. The Dechema and the Committee for Chemical Engineering of the Association of German Engineers will hold their annual meetings and the Association of German Chemists and Association of German Metallurgists will hold special meetings.

Other scientific and technical organizations are expected to meet at the same time.

Sessions on Pipe Lines Held at API Meeting

Sessions during the annual meeting of the American Petroleum Institute at Chicago November 5-8, included the following:

Monday, Nov. 5—Joint meeting, all day:

Committee on Pipe-Line Technology, H. H. Anderson, chairman.

Subcommittee on External Corrosion, L. F. Scherer, chairman.

Subcommittee on Internal Corrosion of Crude Oil Pipe Lines and Tanks, R. A. Brannon, chairman.

Sunday, November 4—Committee on Static and Stray Currents, J. M. Pearson, chairman.

Warning on Corrosive Anti-Freezes Given

"Automotive Antifreezes," available from Superintendent of Documents, Government Printing Office, Washington 25, D. C., for 15 cents a copy gives general information about types of anti-freeze preparations, warning against the use of salt-base and petroleum derived antifreezes as being harmful to the engines of vehicles.

NACE offers a service consisting of abstracts printed on McBee punch cards cross-indexed according to the NACE Abstract Filing System Index on a subscription basis.

Merry Christmas
AND A
HAPPY
Prosperous
NEW YEAR!



SERVICE ENGINEERS, INC.
Registered Professional Engineers
FORT WORTH, TEXAS

Progress Made on Galveston Conference Program

Many symposia officials have been named and definite or tentative arrangements for technical papers completed for the NACE 1952 Conference and Exhibition to be held at Galveston March 10-14. R. L. Bullock, technical program chairman gave the following summary of arrangements completed to date:

Tuesday, March 11

Morning—Registration, business and committee meetings.

2:30 to 4:30 p.m.—**Corrosion Principles Symposium**, Norman Hackerman, Chairman. A color and sound motion picture on general corrosion will be presented by International Nickel Co., Inc. F. L. LaQue of the Inco engineering department will introduce the movie. There will be time for a question and answer period following the movie.

Wednesday, March 12

9:00 to 11:00 a.m.—**Refinery Industry Symposium**, 6 papers. **Marine Industry Symposium**, 4 papers. Dr. Allen L. Alexander, chairman.

2:30 to 4:30 p.m.—**Chemical Industry Symposium**, 6 papers. P. J. Gegner, chairman; C. A. Coberly, co-chairman. **Electrical and Communications Industry Symposium**, 4 papers.

Thursday, March 13

9:00 to 11:00 a.m.—**Refinery-Chemical Industry Symposium**, 6 papers. (Overlapping subject matter included). **Oil and Gas Storage and Transportation Industry**, 4 papers. L. G. Sharpe, chairman.

2:30 to 4:30 p.m.—**Oil and Gas Production Industry Symposium**, 4 papers. H. E. Waldrup, chairman. **Protective Coating Industry Symposium**, 4 papers. A. J. Liebman, chairman; I. L. Whiteneck, co-chairman.

Friday, March 14

9:00 to 11:30 a.m.—**Pipe Line and Underground Corrosion Round Table**, Kirk H. Logan, chairman. **General Corrosion Round Table**, R. B. Hoxeng, chairman.

More Than 70 Booths Sold For 1952 Exhibit

More than 70 of the 105 available booths for the 1952 Exhibit to be held during the annual conference at Galveston, Texas March 10-14 had been requested through November 8. Additional requests for booths are being received daily. The exhibit committee, headed by Jack Harris of Cameron Iron Works, Houston, is busy assigning booths to exhibitors. The committee has scheduled notification of assignments to prospective exhibitors before December 1.

There is reason to believe, Mr. Harris said, all booths will be assigned within the next few weeks.

Army Surface Corrosion To Be New York Topic

R. E. Michele, U. S. Army Corps of Engineers, Washington, D. C. will discuss "Surface Corrosion Prevention Used by the Army Corps of Engineers," at a Metropolitan New York Section meeting December 11. The meeting will be at Building Trades Employers' Association, 2 Park Ave., New York.

Oil and Gas Tentative Program Is Outlined

A tentative program has been proposed by H. E. Waldrup, chairman of Technical Practices Committee 1—Corrosion of Oil and Gas Well Equipment to occupy a full day during the 1952 annual meeting of NACE at Galveston, Texas, March 10-14. The morning session will be devoted to hydrogen sulfide stress cracking and the afternoon to general corrosion of oil and gas production equipment.

Mr. Waldrup's early arrangements indicate all but one of the papers will be prepared by members of the committee.

TP-1 Members Consider Conference Participation

Members of Technical Practices Committee 1 on Corrosion of Oil and Gas Well Equipment have been circularized to obtain a consensus on a proposal to incorporate all or part of a committee conference at Galveston during the 1952 annual meeting there as the Oil and Gas Symposium of the technical program.

If adopted, the proposal provides for a meeting place sufficiently large to accommodate the expected attendance and the necessary sound equipment.

CONSERVES CRITICAL METALS

CONTROLS CORROSION

COSTS LESS



PIPE

•

FITTINGS

•

TUBING



here is the secret...

the BART *LECTROCLAD PROCESS
of lining steel pipe
with nickel—or other anti-corrosive metal

A time tested exclusive development of Bart Manufacturing Corporation during World War II, inspired by the U. S. Government's need for a corrosive-resistant pipe to replace critical nickel and stainless steel. Now LECTROCLAD pipe, fittings and tubing are manufactured and available commercially. Already hundreds of miles are in use in many of the world's largest plants.

*The BART LECTROCLAD PROCESS electrolytically deposits an anti-corrosive metal lining on the interior surface of steel pipe from 1½" to 24" diameter and in 20 foot random lengths. Conserves metal—considerably LESS nickel is used in LECTROCLAD than conventional solid nickel pipe and the cost is approximately TWO-THIRDS LESS.

LECTROCLAD pipe, fittings and tubing are the solution for cost reduction, corrosion protection and contamination for any company that uses corrosive materials in the manufacture of their products.

Write Dept. CM12 today for complete details and technical data.
Names of large users of LECTROCLAD available on request.

BART MANUFACTURING CORPORATION

229 Main Street • Belleville 9, N. J.

Indices to Corrosion Technical Material Published In This Issue

Cross References Given To Technical Section

Published in this issue of Corrosion is the annual Index to Technical Material Published in Corrosion. The tabular cross-referenced tabular index is being used for the second year to classify technical material. The index used is the first two places of the NACE Abstract Filing Index, June, 1951 Revision, which is reproduced in full as part of the index. This index (as was the case with the Index to Volume 6 and the Five Year Index to Technical Material Published in Corrosion, both of which

were part of the December, 1950 issue) will be paginated separately from the remainder of the issue. Those who bind Corrosion technical material by volumes may incorporate the index in the volume readily.

The tabular index has several advantages over indices formerly used:

1. Technical material is listed by title chronologically and in page number sequence, together with page numbers of discussions printed apart from the Article discussed.

2. The tabular index makes possible cross-indexing of the article by subject matter limited only by the extent of the index table. The article may be in-

dexed in one or all of the 70 topics provided with no affect on space used.

How Index Is Used

To locate an article published in Corrosion when the title is known it is necessary to scan the list of articles, which are arranged in the left hand column of the table in chronological order.

To determine if there has been published an article on a topic included in the index, reference first must be made to the index itself. When the topic is located, the numbers applicable to the first heading and the first subdivision of the heading must be used.

Then the first heading number is located at the top of the table. Then under the first heading number the subdivision number is located. Then this column is scanned vertically until a check mark is reached. When a check mark is reached the table then is scanned left horizontally to the name of the article. If no check mark is located, no significant information on the topic has been published in the issue.

Similarly, to determine what significant information can be found in an article, scan horizontally right from the article to locate the check mark or marks. Then by scanning vertically the subdivision and major heading numbers may be located. By reference to the index the subjects related to these numbers may be ascertained.

Author Index

An alphabetically arranged author index also is provided. This index, besides giving the title of the article of which the listed author was the first credited writer, also gives the year and page number in the Technical Section on which the article begins. Under each author's name is listed also the title of each paper to which he has appended a discussion published in the volume, together with the year and page number on which the discussion begins.

In the case of multiple authors, each author after the first author is listed with a reference to the first author only.

The year is incorporated in the author index to facilitate compilation of five and ten year indices of technical material contemplated by the association.

Index to Corrosion Abstracts Is Provided

The Index to Corrosion Abstracts in Volume 6, 1951 (which may be found in this issue as part of the index section immediately following the Technical Section) provides a ready means whereby the researcher may locate by topics the page and month of issue of abstracts.

The topics are those of the June, 1951 Revision of the NACE Abstract Filing Index which is being used also to topically index all technical material in Corrosion and which may be found reproduced in full as part of the Index to Technical Material in Corrosion Volume 6, 1951, in this issue.

Because of redistribution of the several parts of *1.3 Fundamentals* of the November, 1950 version of the NACE Abstract Filing Index over several subdivisions of *3. Characteristic Corrosion Phenomena* of the June, 1951, revision it has been neces-

(Continued on Page 12)

corrosion is
IMPOSSIBLE

in
this
pipe...



The thin coating of cement, mechanically applied and troweled by the Centriline process, raises the pH of any moisture entrapped within the lining to a non-corrosive level—thus prohibiting corrosion or tuberculation. Centrilining also seals holes caused by external corrosion, increases the pipe's carrying capacity thereby reducing pumping and maintenance costs.

Over 1,000 feet of pipe a day can be Centrilined while the pipe remains in the ground! This process—utilizing centrifugal force in applying cement—will give new life to your old pipelines at a fraction of the cost of installing new pipes.

Write today for descriptive literature on lining pipes from 4" to 144" in diameter



CENTRILINE CORPORATION

A subsidiary of
Raymond Concrete Pile Co.

140 CEDAR STREET, NEW YORK 6, N.Y.

Branch Offices in Principal Cities of
United States and Latin America

CEMENT MORTAR LININGS FOR PIPE IN PLACE

ON THE WEST COAST, WRITE AMERICAN PIPE & CONSTRUCTION CO., P. O. BOX 3428, TERMINAL ANNEX, LOS ANGELES, CALIFORNIA

NOW AVAILABLE -- NEW DATA



*For your reference
and use...*

Table of Contents

1.0 History	1
2.0 Need for Cathodic Protection on an Underground Structure	2
2.1 New Structures	2
2.2 Existing Structures	4
3.0 Present Use of Zinc for Cathodic Protection	4
3.1 When to Use Zinc in Preference to Magnesium or Rectifiers	9
3.2 Grades of Zinc for Cathodic Protection Applications	11
3.3 Design of Zinc-Anode Installations	14
3.4 Shape of Zinc Anodes for Various Applications	14
3.5 Necessity for Suitable Backfills for Use with Zinc Anodes	16
3.6 Preparation of Zinc Anodes for Soil Burial	16
3.7 Installation Methods for Zinc Anodes	17
3.8 Use of Zinc Anodes on Structures other than Pipe Lines	18
4.0 Performance Data on Zinc Anodes	20
4.1 Life of Zinc in Soil and Water	21
4.2 Field Test to Determine Performance of Zinc Anode Installation	22
4.3 Zinc Anode Protection on New Construction in Small Towns	24
4.4 Zinc Anode Protection on Old Lines	24
5.0 Instruments Required for Field Tests in Connection With Zinc-Anode Installation	25
6.0 Research Projects on Zinc Anodes	25

ZINC AS A GALVANIC ANODE

A 40-page report prepared for the American Zinc Institute by Ebasco Services, Inc.
from a comprehensive test program

THE NEW JERSEY ZINC COMPANY

160 Front Street, New York 38, N. Y.



HORSE HEAD PRODUCTS

Index to Corrosion—

(Continued from Page 10)

sary to index the page numbers used for 1.8 at appropriate places in 3. Where two page numbers resulted from this operation the duplication has been listed in a footnote.

The index first two places carried as a table ordinate are supplemented by a footnote in which the industries classified under 8, *Industries* are listed. Without this listing it would be necessary to refer to another index before this section would be intelligible.

Because the abstracts published in 1951 were paginated for binding by volume, this year's index uses the serial numbers to be found in the lower outer margins of each page. The affix "a" has

been dropped from the table as superfluous, however. A title page also is provided for those who wish to bind corrosion abstracts separately or who wish to incorporate the abstract section in a bound volume with the Technical Section. The index is printed so it may be used with the title page or separately, as desired.

Page numbers 145a and 146a were omitted in error when the August Corrosion Abstract section was paginated.

Details of an arrangement whereby bound copies of Corrosion material can be secured at nominal cost may be found in this issue.

Requests for lists of literature available from Central Office NACE will be answered promptly.

Some Innovations In Style for Corrosion's Volume 8 to Be Made

The arrangement of material in Volume 8 of Corrosion to be published during 1952 will be substantially the same as that used in Volume 7. There will be some minor innovations in format to improve the usefulness of the magazine in response to suggestions by readers. The principal change will be in adding as a prefix to the titles of topical subdivision headings in the Corrosion Abstract Section, the related number used in the NACE Abstract Filing Index, from which the headings are derived.

Furthermore, Corrosion Abstracts in Volume 8 will be classified under the June, 1951 Revision of the abstract filing index. There are several changes in wording and distribution of topics from the November, 1950 version used to classify abstracts published in Volume 7.

The sequence of material in the magazine is as follows:

Section 1—Roman numbered section. Contains Contents page, Directory of NACE Regional and Sectional Officers, Directory of NACE Technical Practices Committee and a list of names of the officers and members of the board of directors.

Section 2—Technical Section. Numbered serially beginning with Page 1 in January. Contains technical articles approved by the Editorial Review Committee and the Editor of Corrosion.

Section 3—News, Beginning with Page 1 the NACE News Section usually has some or all of the following items: Topic of the Month, Regional and Sectional News, General News of Corrosion Interest, Corrosion Problems, Book Reviews, NACE New Members and Changes of Address, New Products, Personals. Only one page number appears in this part of the magazine.

Section 4—Corrosion Abstract Section. This section has two sets of page numbers. The regular number in the outside upper margin is continuous from the first page of the NACE News section to the last page of the abstract section. In addition, in the lower outer margins, the pages are numbered serially beginning with 1a in January and continuing through the year. The letter "a" indicates "abstract." The first page of the Corrosion Abstract Section also contains the "Index to Corrosion Abstracts" for the issue. The topics under which the abstracts are arranged are indexed by serial page numbers.

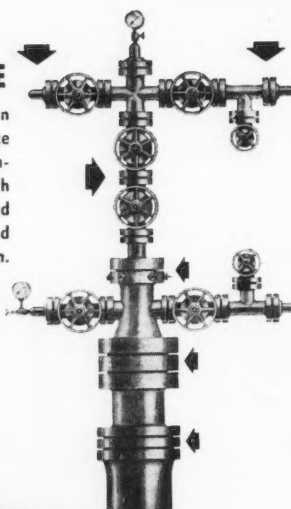
Index numbers carried at the top of each abstract henceforth will consist of three digits separated by periods. The additional third digit is for the third place in the NACE Abstract Filing Index. This position in the index is the one at which random numbers are assigned for indexing abstract punch cards. While this circumstance has no significance necessarily for users of abstracts published in CORROSION, it is advantageous because it gives a more precise breakdown of subject matter and does not affect the validity of the first two places.

Advertising appears only in Sections 1, 3 and 4. The Index to Advertisers usually appears on the next to last, or page facing next to last page in each issue.

There are two sets of serial numbers
(Continued on Page 14)

CORROSION STRIKES HERE

Corrosion in the ring is certain to result when dissimilar metals are flanged up in the presence of a low resistance liquid or electrolyte. Machining of cloth-reinforced plastics exposes the cloth to liquids which hasten deterioration. Forged steel ring gaskets cannot stop this corrosion and alloys frequently increase the rate of corrosion. But it can be eliminated!



STOP
CORROSION
WITH

PESCO
PLASTIC RING SEAL GASKETS

PESCO Gaskets are molded of Fiberglas and a special resin, and provide positive protection against the flow of electric current between dissimilar metals in a joint. They are form fitting under pressure, have high mechanical strength, and are unaffected chemically by any of the gases or fluids encountered in oil and natural gas production or transmission. When used with insulated sleeves and washers around the bolts, PESCO Gaskets will electrically insulate

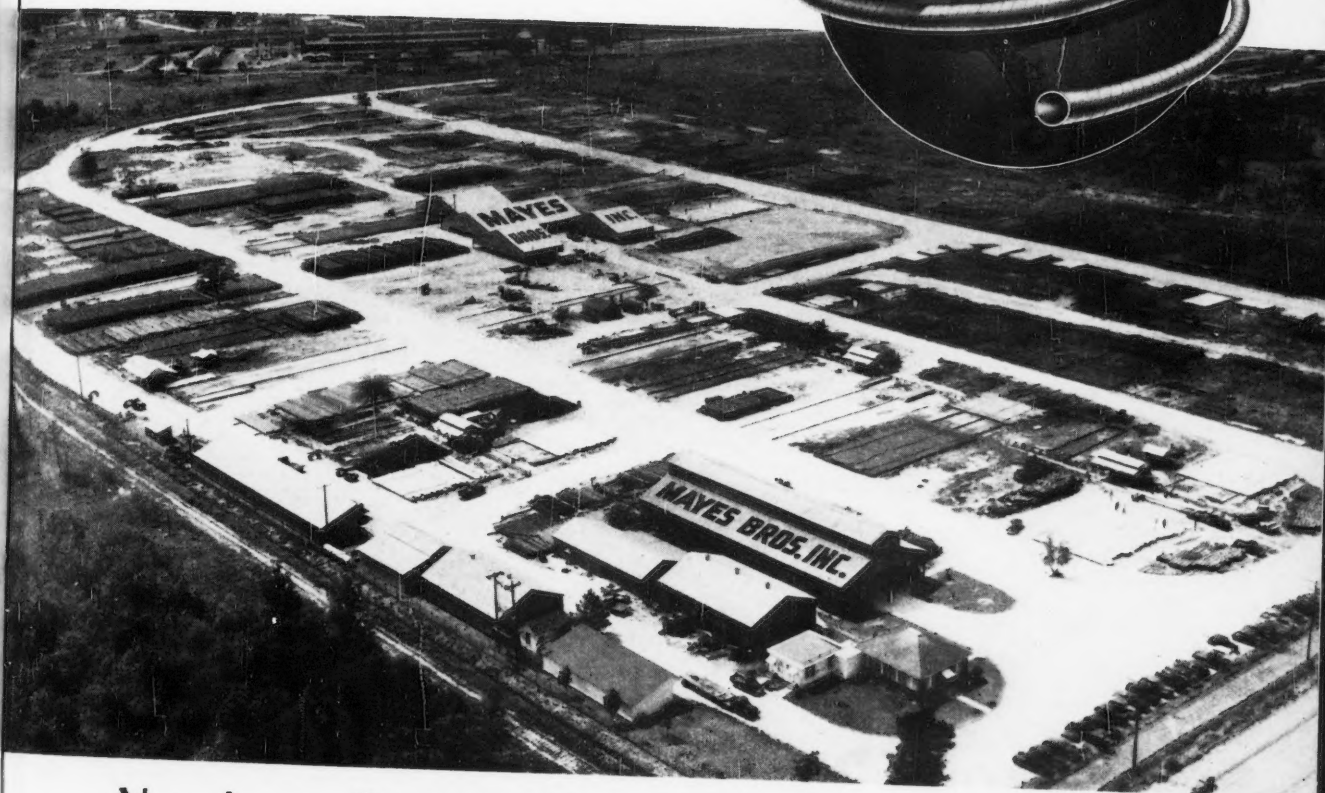
any joint, and will eliminate corrosion caused by galvanic, long line or stray electric currents. Thousands in service on high pressure christmas trees over the past five years. Widely used to insulate well structures against currents flowing from pipe line systems. Investigate PESCO Plastic Ring Seal Gaskets today . . . sizes available to replace metal rings built to API specification 5-G-3. Prices on request.

PLASTIC ENGINEERING AND SALES CORP.

P. O. BOX 1037

FORT WORTH, TEXAS

56 ACRES of PIPE YARD



Nearly a Quarter-Century doing One Job Well

**"PUTTING
Permanence
IN PIPE"**

Our modern plant and equipment, manned by the top hands in the business, is prepared to handle both your new and used pipe jobs, no matter how large or small. Complete reconditioning facilities available.

MAYES BROS.
INCORPORATED
HOUSTON

THE ELSEVIER PRESS



YOU NEED . . .

CORROSION GUIDE

by Erich Rabald

The interest in corrosion is mainly how to combat it. This book shows how at a glance.

Contains tables of the reactions between 250 corrosive agents and 40 standard construction materials together with a short introduction and a bibliography listing references for research on any particular problem.

1951 630 pages 69 folding tables
\$12.50

At your bookseller
or available on approval from

THE ELSEVIER PRESS

402 Lovett Blvd. 445 Park Ave.
Houston 6, Texas New York City

THE ELSEVIER PRESS



Presents a standard work:
by

G. Kortum and J. O'M. Bockris

ELECTROCHEMISTRY

You may have found it difficult to find a definitive text in this relatively new field. Such a work is **TEXTBOOK OF ELECTROCHEMISTRY** by Prof. G. Kortum of Tübingen, translated and brought up-to-date by Dr. J. O'M. Bockris of the University of London. Just published, this book imparts a clear understanding of fundamentals and gives practical data of frequent use to the electrochemist or to those who use electrochemical methods as research tools.

In two volumes:

Vol. I 352 pp 48 illus \$7.00
Vol. II 550 pp 80 illus \$10.00

At your bookseller
or available on approval from

THE ELSEVIER PRESS

402 Lovett Blvd. 445 Park Ave.
Houston 6, Texas • New York City

BOOK REVIEWS

SURFACE CHEMISTRY OF SOLIDS.

By S. J. Gregg. 297 pages, 5½ x 8½ inches. Cloth. Reinhold Publishing Corp., 330 W. 42nd St., New York, N. Y. Per Copy \$8.50.

While the author's interest is concentrated on the nature of the materials, and therefore has given his work the title "Surface Chemistry of Solids," he points out it is "very difficult to delimit surface chemistry from its sister science of surface physics and it is better to regard the two—surface chemistry and surface physics—as constituting a single field of work." The principal discoveries in the field of surface chemistry of solids have occurred in the last 20 years, and the author points out there is a multitude of empirical observations of surface phenomena he has not attempted to organize. The work, rather, is an effort to present an organized study of the basic properties of materials and processes involved at the interfaces of gases, liquids and solids. These interfaces, he states, have properties which differ from either of the materials meeting, but it also is necessary to understand some of the characteristics of the mass of both and the conditions under which the meeting is occurring to fully understand the nature of the interface.

The book, fully illustrated with graphs, contains numerous tables and considers the fundamental phenomena involved in its topic.

The growing importance of surface chemistry in modern industrial processes enhances the importance of this book. Author and subject indices are included.

Some Innovations—

(Continued from Page 12)

in each issue: That for Technical Material and that for Corrosion Abstracts. Every section begins with an odd and ends with an even page so each section may be extracted intact.

Substantial Gains In Editorial Content Made by Corrosion

Substantial increases over 1950 in editorial content, paid circulation and advertising volume were made by **CORROSION** during 1951. Technical section pages numbered 456, an increase of 42 pages or about 10 percent. This material consisted of 74 titles, while all authors contributing material to the technical section numbered 160. This represents an increase of 14 titles over the 60 published in 1950, or 23 percent. The number of authors listed in the 1951 index is 160, making an increase in 1951 of 20 authors over the preceding year, or 14 percent.

Increases in other subdivisions were as follows (Figures for 1951 tentative): Total pages advertising, 1951, 433; 1950, 359; increase, 74 pages or 19 percent. Number of pages of news, 1951, 195; 1950, 203, decrease, 9 pages or 5 percent. Number of pages of abstracts, 1951, 119; 1950, 115; increases, 4 pages or 3 percent. Total number of pages, including cover, 1951, 1214; 1950, 1152; increase, 62 pages or 5 percent.

The average net gain in paid circulation for January-June, 1951, inclusive, over the 12-month average for 1950 was 642, or 20 percent. Figures for the year have not been compiled.

Thermodynamics Book Available In France

The Proceedings of the Second Meeting of the International Committee of Electrochemical Thermodynamics and Kinetics was reviewed in the November issue of **CORROSION** in addition to being available from the publishers, also may be secured from Dr. Marcel Pourbaix, CITCE, University of Brussels, Avenue F. D. Roosevelt, 50, Brussels, Belgium.



the Silent Watchman

On completely re-conditioned jobs, the painting is guaranteed for five years, repairs guaranteed for ten years, provided the tank is painted every five years. Yearly inspection, making all adjustments, if any, without additional cost.

Write Us for Free Copy of Publication

SOUND PRINCIPLES OF WATER TANK MAINTENANCE and TANK TALK

by W. A. Riley

DIXIE'S NATION WIDE SERVICE SATISFIES

Copyright 1951

THE LARGEST ORGANIZATION OF ITS KIND GIVING SAFE MAINTENANCE AT LOW COST

DIXIE TANK and BRIDGE CO.

3523 Lamar Ave.—P. O. Box 14, MEMPHIS 1, TENNESSEE

Complete Service for Elevated
Water Tanks—

NATION WIDE SERVICE—

33 Years Experience

KEEP THE SAFETY FACTOR IN
YOUR TANK THE DIXIE WAY

By welding seams, pits and rivets which gives a riveted tank 15% more Safety Factor than it had when built. No rivets removed, water supply maintained while work is in progress.



Mountain-climbing pipe line being laid for keeps!

IT'S PROTECTED BY BITUMASTIC ENAMEL!



THE 26-INCH natural gas pipe line, shown here, was laid across the most mountainous part of West Virginia for the Atlantic Seaboard Corporation. Here's a sample of what the pipe liners were up against: at one point the face of Cave Mountain rose at an average rate of 45 degrees, climbing for 1,700 feet before easing off to a more gradual slope.

When pipe lines are laid under such back-breaking conditions, they *must* go down to stay . . . they *must* be fully protected against corrosion. That's why this pipe line was coated with Bitumastic® 70-B Enamel.

Bitumastic® Enamels have established remarkable records in preventing corrosion — under the most severe corrosive conditions . . . in all types of soil . . . under wide variations of temperature. Thanks to these durable enamels, many gas and oil pipe lines, laid 20 and 30 years ago, are still giving good service today.

Specify Bitumastic Enamels and make certain *your* pipe-line projects get the most effective protection against corrosion. Your Koppers representative will give you complete details and estimates.



**Bitumastic Enamels soon available
from Koppers new California Plant!**

As soon as present construction work is completed, Koppers will be able to supply Bitumastic Enamels from a new plant at Fontana, California. The plant is being built to give you better service in the West.



BITUMASTIC ENAMELS
REG. U.S. PAT. OFF.

KOPPERS COMPANY, INC., Tar Products Division, Dept. 1204-T, Pittsburgh 19, Pa.

DISTRICT OFFICES: BOSTON, CHICAGO, LOS ANGELES, NEW YORK, PITTSBURGH AND WOODWARD, ALABAMA

Research Facilities of Crerar Library Listed

Literature research facilities of the John Crerar Library, a privately endowed free public library located in Chicago at the corner of Randolph and Michigan Ave., are available on a fee basis to companies and individuals. The library's resources include about 750,000 volumes in the fields of science, technology and medicine and current subscriptions to thousands of technical scientific periodicals.

The library's Research Information Service provides on a fee basis the following services:

Exploratory Search—Gathering news

on a broad basis. The report usually takes the form of a bibliography with informative abstracts or a technical report.

Author-Title Bibliography—Contains books, journal articles published during designated years or unlimited; only English language material or foreign material; one element of a problem or a selection of more important articles. It may be arranged in several ways.

Annotated Bibliography—With helpful notes on content.

Bibliography with Informative Abstracts—More extensive abstracts.

Technical Report—Critical review of the literature and a report on conclusions, with references.

Periodic Reports on Current Literature.

Prior Art Searches—Related to Patents.

Data Search—A review to ascertain specific items of information.

Translations—or extensive abstracts or summaries. The RIS staff includes translators in the important European languages.

Reimbursement is on a time per hour basis, normally at \$5.25 per hour for professional services, proportionately lower rates for clerical assistance and monthly rates for continuing service. Translation fees are based on a 100-word rate varying for different language groups.

The library staff includes subject specialists competent in most fields and special personnel may be employed for continuing or special projects. All work is done in confidence.

Details on the Research Information Service can be secured by writing to: Research Information Service, The John Crerar Library, 86 East Randolph St., Chicago 1, Ill.

Photostat and microfilm service information may be obtained from: Photoduplication Service, The John Crerar Library, 86 East Randolph St., Chicago 1, Ill.

German Testing and Measuring Advances Cataloged in Magazine

A special issue of the German trade magazine "Progressus," detailing West German achievements in the field of testing and measuring has been sent to NACE by the German-American Trade Promotion Office, 350 Fifth Ave., New York 1, N. Y. The issue, No. 3 of 1951, is in English and contains illustrations and descriptions of a wide range of instruments, including precision measuring instruments for progressive production, innovations in electrical measuring techniques, new optical precision measuring instruments for gauging workpieces, pressure and temperature measuring instruments, modern differential analyzers for differential equations, mathematical instruments for measuring and computing, and mathematical instruments.

"Gear Research as a Basis for Gear Mechanism Practice," by G. Fischer and Obering, Th. Lance, Stuttgart is an article discussing this topic and illustrating the use of certain specialized instruments for this field.

Information about membership in NACE will be sent on request to persons interested.

CORROSION
SCALE AND ALGAE

Controlled
IN
PETROLEUM PLANTS
BY
HAERING ORGANIC GLUCOSATES*

Quachrom Glucosate
Sodium Chrom Glucosate
Tetra Phospho Glucosate
Pyro Glucosate

REG. U.S. PAT OFF

Over years of service these Glucosates have an unexcelled record of satisfactory performance

WRITE ON YOUR LETTERHEAD FOR SPECIAL LITERATURE

D. W. HAERING & CO., INC.



GENERAL OFFICES

P. O. BOX 6037, SAN ANTONIO, TEXAS

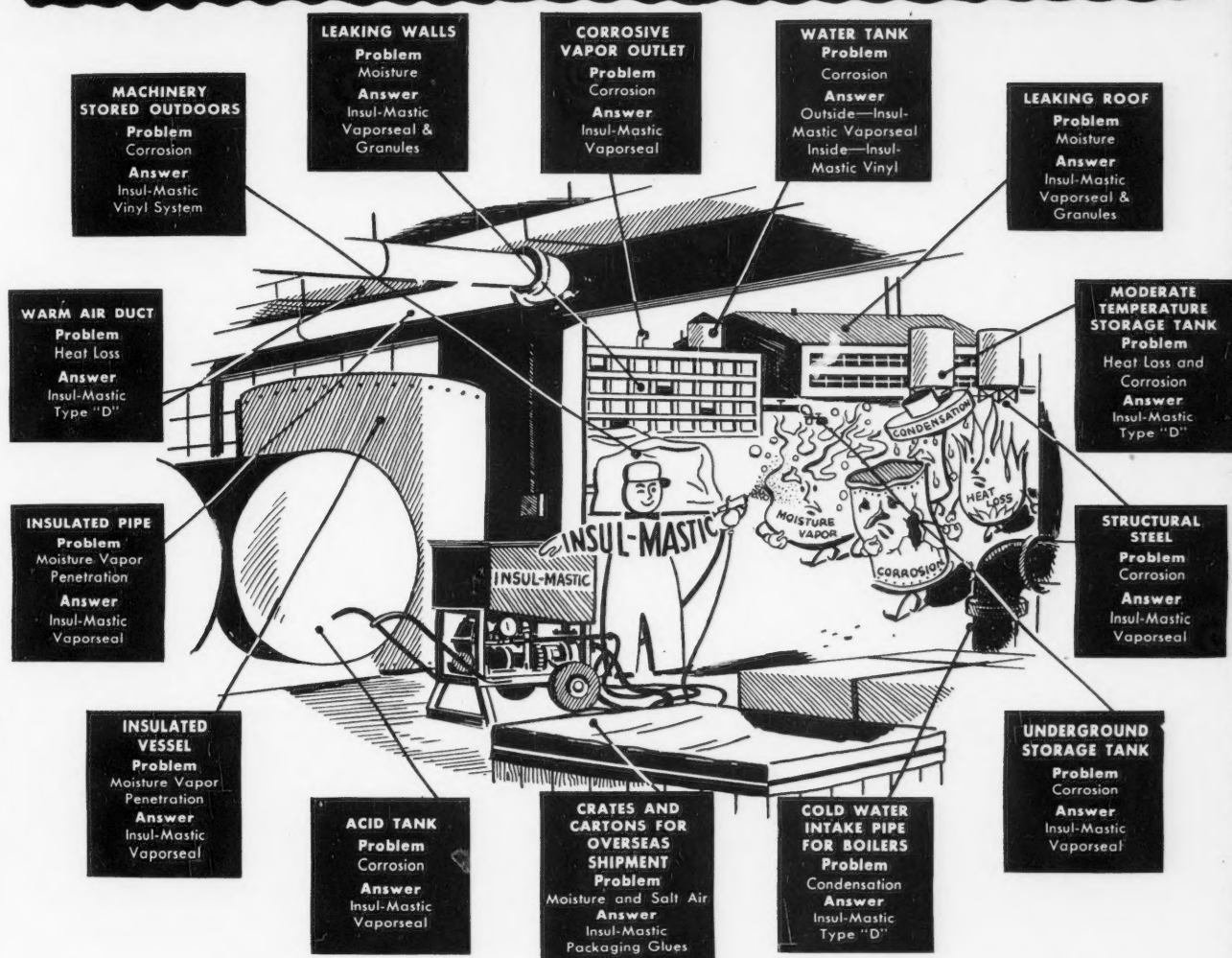
CHICAGO OFFICE: 205 West Wacker Drive

DISTRICT SALES MANAGER OHIO AREA

To market metal treating compounds: phosphating materials cleaners, rust removers, strippers.

We want aggressive men with a solid technical background and good contacts in manufacturing plants. The competition is tough, but you will be selling a superior product. Excellent opportunity with growing organization. Please write fully. All replies will be held in strict confidence. Sales Manager, Octagon Process, Inc., 15 Bank St., Staten Island, N. Y.

WHERE WILL THEY ATTACK IN YOUR PLANT?



PROTECT YOUR EQUIPMENT WITH
INSUL-MASTIC
COATINGS OF UNEQUALED QUALITY

You can't select a heavy coating of better quality than Insul-Mastic. Its ingredients were specially chosen for their stubborn resistance to acids, alkalis, weather and wear. Insul-Mastic is homogenized for smooth spraying without blobs or pinholes. Write today for our catalog.

*Think first of the
coatings that last!*

Insul-Mastic Corporation
OF AMERICA

1164 OLIVER BUILDING · PITTSBURGH 22, PA.
Representatives in Principal Cities



NACE

New Members and Changes of Address

• This list is published principally for use by NACE Regional and Sectional officers in keeping their mailing lists up to date.

NEW MEMBERS

(Additions Through October 27, 1951)

ARKANSAS

MADDOX, MELVIN E., Reilly Tar & Chemical Corporation, 124 Pine Valley Road, Little Rock, Arkansas.

CALIFORNIA

JOHANNESSEN, CLIFFORD W., Paddock Engineering Company, 8400 Santa Monica Blvd., Los Angeles 46, California.
SIMMONS, WILLIAM P., Alloy Steel Products Company, 24 California Street, San Francisco, California.
SMITH, ADRIAN W., 2011 32nd Avenue, San Francisco, California.
TERRY, FRED P., East Bay Municipal Utility District, 22nd & Adeline Streets, Oakland, California.
WHITMAN, JOHN E., Hunt Process Company, 7012 Stanford Avenue, Los Angeles 1, California.

FLORIDA

GERMAN, COMMANDER JOHN P., United States Coast Guard, 2610 Tiger Tail Avenue, Miami 33, Florida.

ILLINOIS

DUFFNER, GORDON H., 1749 East 83 Street, Chicago 17, Illinois.
KLASSEN, CLARENCE W., Division of Sanitary Eng., State Dept. Public Health, Capitol Building, Springfield, Illinois.
KROON, HARRY E., Illinois Bell Telephone Company, 1025 Sunnyside, Chicago 40, Illinois.
LOGAN, ROBERT L., International Minerals & Chemical Corp., 29 North Wacker Drive, Chicago 6, Illinois.
LYONS, ROBERT H., Bridgeport Brass Company, 3453 West 47th Place, Chicago 32, Illinois.
ROULAND, E. E., Reilly Tar & Chemical Corporation, P. O. Box 370, Granite City, Illinois.

KANSAS

WEISER, LeMOINE D., Southwestern Bell Telephone Company, 512 Mills Building, Topeka, Kansas.

KENTUCKY

FISKE, C. WALTER JR., Sales Engineering Inc., 136 Breckenridge Lane, Louisville 7, Kentucky.

LOUISIANA

MULLINS, JOHN D., Union Sulphur & Oil Corporation, Pioneer Building, Lake Charles, Louisiana.
TOOLAN, FRANCIS P., The Flintkote Company, 4500 North Galvez Street, New Orleans, Louisiana.

MICHIGAN

HILL, DAVID L., Timken Detroit Axle Company, 100-400 Clark Avenue, Detroit, Michigan.

MISSOURI

GEORGI, CHARLES D., Protective Coatings Company, 2626 Sidney Street, St. Louis 4, Missouri.

NEW JERSEY

EISENMANN, CHARLES E., 3 Hull Drive, Raritan Township, New Brunswick, New Jersey.
GRIFFITHS, CHARLES W., R. M. Hollingshead Corporation, 16th & Mickie Streets, Camden, New Jersey.
LOWENHEIM, FREDERICK A., Metal & Thermite Corporation, P. O. Box 471, Rahway, New Jersey.
MORRISON, BARCLAY, The Carpenter Steel Company, Alloy Tube Division, Union, New Jersey.
WATSON, JOHN A., Jr., Minnesota Mining & Manufacturing Company, 700 Grand Avenue, Ridgefield, New Jersey.

NEW YORK

LAKE, FRANCIS J., Consolidated Edison Co., Inc., 4 Irving Place, New York, New York.
LEWIS, SIDNEY A., United States Stone-ware Company, 60 East 42nd Street, New York 17, New York.
LINFORD, HENRY B., Dept. of Chemical Engineers, Columbia University, 119 Street & Broadway, New York 27, New York.

SCHLEICHER, MARTIN E., McDougall-Butler Company, Inc., 2929 Main Street, Buffalo 14, New York.

OHIO

FALCK, SYLVAN B., Inner-Tank Lining Corporation, 1097 Wade, Cincinnati 29, Ohio.

OKLAHOMA

GOODNIGHT, ROBERT H., Stanolind Oil & Gas Company, 1136 North Lewis, Tulsa, Oklahoma.
HORNER, WILLIAM L., Sunray Oil Corporation, First National Building, Tulsa 3, Oklahoma.

PENNSYLVANIA

COCHRAN, WILLIAM C., Aluminum Company of America, Aluminum Res. Labs., Freeport Road, New Kensington, Pa.
COSTELLO, CARL C., 1234 Roosevelt Drive, Llanerch, Pa.

TEXAS

BERG, MARTIN, 5210 Westchester, Houston, Texas.
BILLINGS, THOMAS J., Thornhill-Craver Company, 1111 Lockwood, Houston, Texas.
BLACKBURN, PHILIP C., Extension Div., University of Texas, Drawer "D", University Station, Austin, Texas.
COLLINS, JOHN W., 3230 Willowood Drive, Beaumont, Texas.
DEBORD, GEORGE E., 1318 Wolf Street, Galena Park, Texas.
FUCHS, FRITZ E., Aquanex Corporation, 2905 Quitman, Houston, Texas.
HALLORAN, WILLIAM D., Duriron Company, Inc., 682 M & M Building, Houston, Texas.
IRVING, RALPH, Vapor Honing Company, 515 Sterling Building, Houston, Texas.
KIRKPATRICK, WILLARD H., Visco Products Company, Inc., P. O. Box 295, Sugar Land, Texas.
MCUTCHEEN, CHARLES W., The Dow Chemical Company, Building A-906, Freeport, Texas.
NEAVES, CAROL L., Lone Star Gas Company, Dallas Division of Distribution, 301 S. Harwood, Dallas, Texas.
PETTITHONE, ROBERT H., Minnesota Mining & Mfg. Company, 1221 Dragon, Dallas, Texas.
STOCKDALE, HAROLD L., Industrial Waterproofing Company, 2318 Sul Ross, Houston 6, Texas.
STOKES, JAMES H., Gulf Refining Company, Houston Pipe Line Division, P. O. Box 1203, Houston, Texas.
SWOPE, JOHN G., JR., Carbide & Carbon Chemicals Company, Texas City, Texas.
THORNTON, WILLIAM N., 5623 Loring Drive, Dallas, Texas.

WISCONSIN

PLOEDERL, FRANCIS J., Wisconsin Protective Coating Company, 426 Elizabeth Street, Green Bay, Wisconsin.
VOGEL, HENRY A., Pittsburgh Plate Glass Company, 235 East Pittsburgh Avenue, Milwaukee 1, Wisconsin.

FOREIGN

STUBBS, THOMAS L., Canadian Industries Limited, Eng. Dept., P. O. Box 10, Montreal, Quebec, Canada.
WILCOCK, WALTER, Union Gas Company of Canada, Ltd., 521 McDougall, Windsor, Ontario, Canada.
TUPHOLME, CHARLES B., Samuel Fox & Company, Ltd., Stocksbridge Works, Nr. Sheffield, England.
VAN DER VELDE, J. C., Fa. J. C. Van Der Velde-Henning Franzen, Hofwijckplein 32, The Hague, Holland.
TANAKA, MICHIO, Kansai Denryoku K. K., Tech. Lab., 1-Chome, Kujo-Minami-dori, Mishi-ku, Osaka, Japan.

CHANGES OF ADDRESS

(Old Address Follows New in Parenthesis)

CALIFORNIA

COLYER, DAVID J., JR., The Duriron Company, Inc., 214 N. Canon Drive, Beverly Hills, California, (450 No. Findley St., Dayton, Ohio).
ELSENER, L. A., Chicago Bridge & Iron Company, 290 Bush Street, San Francisco 4, California, (11).
HILL, PRESTON W., Signal Oil & Gas Company, 2501 East Willow, Long Beach, California, (2301).

GEORGIA

TRAPP, RAYMOND F., 3431 Sherman Road, Hapeville, Georgia, (Midwestern Engine & Equipment Co.).

ILLINOIS

LOUDENBACK, CLYDE I., 7641 Luella Avenue, Chicago 49, Illinois, (Dearborn Chemical Co., 310 S. Michigan Avenue, 4).
ROSE, PHILIP E., 6930 South Shore Drive, Chicago 49, Illinois, (Phillip).
SALLE, WILLIAM H., Commonwealth Edison Company, 72 W. Adams Street, Room 818, Chicago 90, Illinois, (Add Room 818).

SWANBECK, LEONARD W., P. O. Box 184, St. Jacob, Ill. (E. A. Oberling Oil Company).

ZAUNER, JOHN HUDSON, Eureka Williams Corporation, Bloomington, Illinois, (Creole Petroleum Corp., Cabimas, Estado Zulia, Venezuela, S. A.).

INDIANA

MANKIN, PAUL A., Bowser, Inc., 1302 E. Creighton Ave., Fort Wayne, Indiana, (Port).

KENTUCKY

CREEVY, JOSEPH A., Newport Steel Corporation, Ninth & Lowell Sts., Newport, Kentucky.
GOTTIEBSEN, LENIUS H., General Electric Company, Water Heater Eng., 310 West Liberty, Louisville 2, Kentucky, (1285 Boston Avenue, Bridgeport 2, Connecticut).

LOUISIANA

FRIZELL, GLENN H., 103 E. Slattery, Frizell, Louisiana, (Electro Rust-Proofing Corp. N. J., First National Bank Bldg.).
GARNER, CORDELLE L., P. O. Box 85, Broussard, La. (Tube Kote, Inc., 2520 Holmes Road, Houston, Texas).
INGRAM, SIDNEY M., 4503 Steers Drive, Shreveport, Louisiana, (Turco Products, Inc., 1305 Marshall Street).
MCALLUM, WALTER C., JR., 170 Starlin Street, Sulphur, Louisiana, (85 Beauregard Ave., Maplewood, La.).
NILL, JULIUS H., Metallizing Eng. Co., Inc., 224 Humble Bldg., New Orleans 15, Louisiana, (1734 Candler Bldg., Atlanta, Georgia).

MASSACHUSETTS

BIRD, J. D., The Dampney Co. of America, 1243 River, Hyde Park, Boston 36, Mass. Hyde Park).
KELLEY, HOWARD M., Chemical Fire & Rust Proofing Corp., 985 Metropolitan Ave., Hyde Park, Mass. (84½ Berkeley, St., Boston, Massachusetts).
PIERCE, EDGAR M., The Pierce Consulting Eng. Co., 183 Essex St., Boston, Mass. (683 Atlantic Ave., 11.).

MICHIGAN

KENNEDY, TED, Trenton Corp., 401 Wolverine Bldg., Ann Arbor, Michigan, (408).

MISSOURI

ELLWOOD, EDWARD E., Reynolds Metals Co., 4144 Lindell Ave., St. Louis 8, Missouri, (Steel Sales Corp., 4565 McRee, St. Louis 10, Mo.).

NEW JERSEY

BARNES, FRANK H., P. O. Box 142, Cranford, N. J. (42 West Holly St., Cranford).
ENGLISH, E. ROWLAND, Pipe Protection Service, Inc., 10 Center St., Elizabeth, New Jersey, (H. C. Price Company, P. O. Box 6120, Philadelphia, Pennsylvania).
FASIG, PAUL L., 83 Aberdeen Place, Woodbury, N. J. (173 Leeds Place).
MCWHORTER, SAM B., 1025 Plainfield Avenue, Plainfield, New Jersey, (7 Poe Ave., New Brunswick, N. J.).
OXLEY, GEORGE W., 1115 Galloping Hill Road, Elligabeth 3, New Jersey, (Standard Oil Development Co.).
SHENTON, F. GEORGE, Rd. 1, Monroeville, New Jersey, (Route 1).
THORNE, ANTHONY Z., 139 Maybrook Drive, Maywood, N. J. (Tide Water Associated Oil Co., E. 22nd Street, Bayonne, New Jersey).

NEW YORK

GERMAN, ALFRED, Scovill Manufacturing Company, Chrysler Bldg., 405 Lexington Ave., N. Y., N. Y.
GRUBER, K. A., Chemical Fire & Rust Proofing Corp., 11-33 31st Drive, Long Island City 6, N. Y. (508 East 117th Street, New York 35, N. Y.).
HALE, WILLIAM L., The Debevoise Co., 74 20th St., Brooklyn 32, New York, (84).
McGLOTHLIN, BRUCE B., JR., 564 Delaware St., Buffalo, New York (Room 503, Downtown YMCA, 45 W. Mohawk St.).
SHIELDS, JAMES E., Alois Corp., P. O. Box 55, Niagara Falls, New York, (3943 Buffalo Avenue).

OHIO

BAKER, GERALD ARTHUR, Keller Hall, Springfield, Ohio, (412 West Santa Clara Ave., Santa Ana, Calif.).
SHAW, WILLIAM E., National Lead Co. of Ohio, P. O. Box 158, Mt. Healthy Station, Cincinnati 31, Ohio, (Titanium Alloy Mfg. Div., Box C Bridge Station, Niagara Falls, New York).

OKLAHOMA

BRADLEY, BRYANT W., 4520 E. 6th Street, Tulsa, Okla. (Shell Oil Company).

(Continued on Page 20)

NI-RESIST® CASTINGS PRODUCED IN ALL IMPORTANT INDUSTRIAL AREAS...

Your Complimentary Copy of "Engineering Properties and Applications of Ni-Resist" is Ready at the Nearest Authorized Ni-Resist Foundry Listed . . . Write for it Now.

Abrasive Alloy Castings Co., Bridgeboro, N. J.
American Brake Shoe Co., New York 17, N. Y.
American Brake Shoe Co., Electro-Alloys Division, Elyria, Ohio

American Brake Shoe Co., Engineered Castings Division, Rochester 11, N. Y.

American Cast Iron Pipe Co., Birmingham 2, Ala.
American Chain & Cable Co., Inc., Reading Steel Casting Division, Reading, Pa.

Baker Perkins, Inc., Saginaw, Michigan

Baldwin-Lima-Hamilton Corp., Eddystone Division, Philadelphia 42, Pa.

Barnett Foundry Co., Irvington, N. J.

Buffalo Stainless Casting Corp., Buffalo 11, N. Y.

Carondelet Foundry Co., St. Louis 10, Mo.

Centrifugal Casting Co., Long Beach 7, Calif.

Chicago Hardware Fdry. Co., The N. Chicago, Illinois

Chris. Erhart Fdry. & Mach. Co., The Cincinnati 3, Ohio

Dameron Metal Sales Co., Compton, Calif.

DeZurik Shower Co., Fdry. Div., Sartell, Minn.

Duluth Brass Works Co., Duluth, Minn.

Duriron Co., Inc., The, Dayton 1, Ohio

Eagle Foundry Co., Seattle 4, Wash.

Electric Steel Foundry Co., Portland 10, Ore.

Elizabeth Street Foundry Co., Chicago 36, Ill.

Engineering Castings, Inc., Marshall, Michigan

Fahrlay Co., The, Harvey, Ill.

Frank Foundries Corp., Moline, Ill.

General Metals Corp., Oakland 3, Calif.

Golden's Foundry & Mach. Co., Columbus, Ga.

Hamilton Foundry & Mach. Co., Hamilton, Ohio

Hunt-Spiller Manufacturing Corp., South Boston 27, Mass.

Janney Cylinder Co., Philadelphia 36, Pa.

Kingsport Foundry & Mfg. Corp., Kingsport, Tenn.

Koppers Co., Inc., Metal Products Division Baltimore 3, Md.

Kutztown Foundry & Machine Corp., Kutztown, Pa.

Michiana Products Corp., Michigan City, Ind.

Michigan Steel Casting Co., Detroit 7, Mich.

Montague Machine Co., Turners Falls, Mass.

Moran Flexible Joint Co., Inc., Louisville 2, Ky.

Olney Foundry, Link-Belt Co., Philadelphia 20, Pa.

Pacific Foundry Company, Ltd., San Francisco 10, Cal.

Peru Foundry Company, Peru, Indiana

Pusey & Jones Corp., The, Wilmington 99, Del.

Reda Pump Co., Bartlesville, Okla.

Richmond Foundry & Mfg. Co., Inc., The Richmond 20, Va.

Ross-Meehan Foundries, Chattanooga 1, Tenn.

St. Paul Foundry & Mfg. Co., St. Paul 3, Minn.

Shenango-Penn Mold Co., Dover, Ohio

Standard Brass & Mfg. Co., Port Arthur, Texas

Stanley Foundries, Huntington Park, Calif.

Sterling Foundry Co., The, Wellington, Ohio

Taylor & Fenn Co., The, Hartford 1, Conn.

Texaloy Foundry Co., San Antonio 3, Texas

Thomas Foundries, Inc., Birmingham 1, Alabama

Trinity Valley Iron & Steel Co., Fort Worth, Texas

W. S. Tyler Co., The, Cleveland 14, Ohio

Weatherly Foundry & Mfg. Co., Weatherly, Pa.

Wells Manufacturing Co., Skokie, Ill.

Westlectric Castings, Inc., E. Los Angeles 22, Calif.

United States Pipe and Foundry Co. Burlington, N. J.

Utility Steel Foundry, Vernon (L. A.), Calif.

Zenith Foundry Co., West Allis 14, Wis.

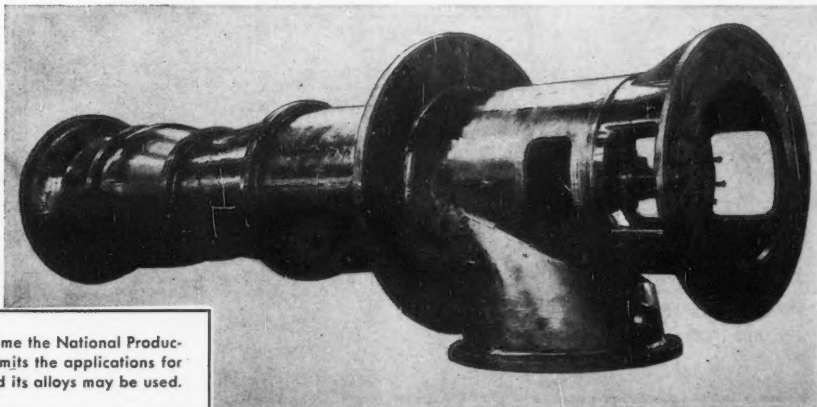
Ni-Resist provides a unique combination of engineering properties: resistance to corrosion, heat and wear; strength and toughness; good machinability; high electrical resistance and, by suitable choice of nickel content, non-magnetic characteristics and high and low thermal expansion. A few typical instances of the numerous successful applications are shown below.



↑ Medium Castings . . . Free from tendencies to corrode, comminutor parts cast in Ni-Resist lengthen life of sewage disposal equipment.



↑ Light Castings . . . These piston rings are produced in Ni-Resist for engines used in corrosive service.

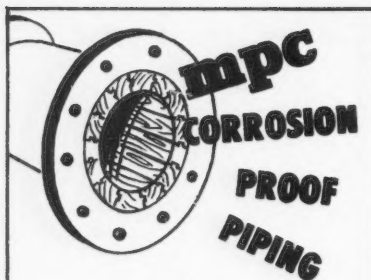


↓ Heavy Castings . . . Casing, outer column and discharge head of this 14-ton pump are cast in Ni-Resist for resistance to salt water and other corrosive media.



At the present time the National Production Authority limits the applications for which nickel and its alloys may be used.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.



for dependable, trouble-free service
specify MPC

- wood stave pipe
- wood lined steel pipe
- saran rubber lined steel pipe
- stainless steel tubing
- monel metal tubing

Piping and fittings engineered to
your particular requirements. Ideal
for acid, alkali and saline service,
also chemical gases, solvents, pulps,
bleaching liquors and aggressive wa-
ters. Write Dept. C for recommenda-
tions on your specific piping problems.



Bay City • Michigan

Changes of Address—

(Continued from Page 18)

CARDWELL, PAUL H., Dowell Inc., P. O.
Box 536, Tulsa, Oklahoma. (524 Kennedy
Building.)
GROOM, CLAUDE H., Dowell, Inc., P. O.
Box 536, Tulsa, Oklahoma. (524 Kennedy
Building.)
HUGHES, ELLSWORTH W., Dowell, Inc.,
P. O. Box 536, Tulsa, Oklahoma. (Ken-
nedy Building.)
HUGO, L. A., Phillips Petroleum Co., Bart-
lesville, Oklahoma. (M. E. Holmberg.)
NODURFT, HARRY M., Consolidated Gas
Utilities Corp., P. O. Box 303, Weather-
ford, Oklahoma. (Noduret)
TITTERINGTON, Y. W., Pipeline Mainte-
nance Corp., P. O. Box 1424, Tulsa, Okla-
homa. (Dowell, Inc., 529 Kennedy Bldg.,
Tulsa 3.)
WALTHER, HERBERT H., Dowell, Inc., P.
O. Box 536, Tulsa, Oklahoma. (Kennedy
Building.)
WILLIAMS, GUY F., Dowell, Inc., P. O. Box
536, Tulsa, Oklahoma. (524 Kennedy
Building.)

PENNSYLVANIA

KAMPS, JULIUS M., Koppers Co. Inc., 403
Chamber of Commerce Building, Pitts-
burgh 19, Pennsylvania.
KELLER, Richard M., 5368 Magnolia Avenue,
GTN, Philadelphia 44, Penna. (Keystone
Pipe Line Co.)
POPE, ROBERT, P. O. Box 231, Quakertown
R. D., 4, Pennsylvania. (Applebach-
ville, 3.)
WHITTIER, FREDERICK, 1094 Riehl Ave.,
Apt. 2, Castle Shannon, Pittsburgh 34,
Pennsylvania. (United States Testing Co.
Inc., 1415 Park Avenue, Hoboken, New
Jersey.)

TENNESSEE

McLAREN, JAMES, Oak Ridge National
Laboratory, Bldg. 3026, P. O. Box P,
Oak Ridge, Tennessee. (103 Norman Lane,
Oak Ridge, Tennessee.)
WADE, PAUL A., 118 Roland Avenue, Jack-
son, Tennessee. (P. O. Box 485, El Campo,
Texas.)

TEXAS

ALEXANDER, ROBERT C., JR., 4903 Maple
Street, Bellaire, Texas. (1122 Theresa
Street, Houston 4, Texas.)
BENDER, RICHARD, B., Plastic Eng. &
Sales Corp., P. O. Box 1037, Fort Worth,
Texas. (634 W. Temple, Houston 9,
Texas.)

GREGORY, MILTON W., 9315 San Fernando
Way, Dallas, Texas. (Glass Fibers, Inc.,
1819 Madison Ave., Toledo 2, Ohio.)
HEINEN, LAWRENCE E., Tube-Kote, Inc.,
P. O. Box 20037, Houston 25, Texas. (8123)
HENRY, ERNEST L., P. O. Box 173, Cleve-
land, Texas. (P. O. Box 122, Bonham,
Texas.)
HOLM, EMIL G., Tube-Kote, Inc., P. O. Box
20037, Houston 25, Texas. (8123)
HOLT, JAMES B., City of Dallas, 2014 W.
Melbourne St., Dallas 8, Texas.
LINGLE, ROBERT J., 2009 Fannin, Suite 30,
Houston, Texas. (Pittsburgh Coke &
Chemical Co., P. O. Box 13126, Houston.)
LOCHEED, E. W., 133 Brace Street, Houston
17, Texas. (American Republics Corp.,
Petroleum Bldg.)
ROGERS, WALTER F., Gulf Oil Corp., 5311
Kirby Drive, Houston, Texas. (P. O.
Drawer 2100, 1.)
STEPHENS, THOMAS O., 1001 A North
Crawford, Dallas, Texas. (Amercoat Corp.,
4809 Firestone Blvd., South Gate, Calif.)
WOOD, HERSCHEL J., Lebanon Steel
Foundry, 1505 Commerce Bldg., Houston
2, Texas. (Hershel)

WASHINGTON, D. C.

LEAS, A. ROBERT, 1026 17th St. N. W.,
Washington, D. C. (Williams Bros. Corp.)

WEST VIRGINIA

KOEHLER, W. A., West Virginia University,
Mineral Industries Bldg., Morgantown,
W. Va. (Morgantown)
VAN PETTEN, CLIVER W., Columbian Car-
bon Co., P. O. Box 873, Charleston, W.
Va. (Petton)

FOREIGN

WATSON, T. R. B., Corrosion Service, Ltd.,
77 York St., Toronto, Ontario, Canada.
(Dominion Magnesium, Ltd., Suite 1505,
320 Bay St.)
OOSTERWJJK, A. R. KOLFF VAN, c/o Messr.
Hertel & Co., Grasweg 49, Amsterdam,
Holland. (Laboratorium Koninklijke Shell,
Badhuisweg 3, Amsterdam, Holland.)

NEW CORPORATE MEMBER

WHEELING STEEL CORP.,

Wheeling, West Virginia

Henry A. Stobbs, Representative

STOP CORROSION BEFORE IT STARTS

Asbestos Pipe Line Felt is time tested and proven on the
line. WHY EXPERIMENT?

Asbestos Pipe Line Felt has been used to protect under-
ground pipe coatings for more than a quarter of a century.
The coatings on thousands of miles of lines are protected by
Asbestos Felt. Most major pipe line companies have personal
experience as to its effectiveness.

NICOLET Asbestos Pipe Line Felt is not a thin foreign
product in the enamel, but a rugged 15-lb. inorganic shield
which protects the enamel insulation on the outside—where
corrosion starts. NICOLET Felt is saturated with the same
basic bitumens as the coating.

WRITE FOR
LITERATURE
AND PRICES

NICOLET* ASBESTOS PIPE LINE FELT

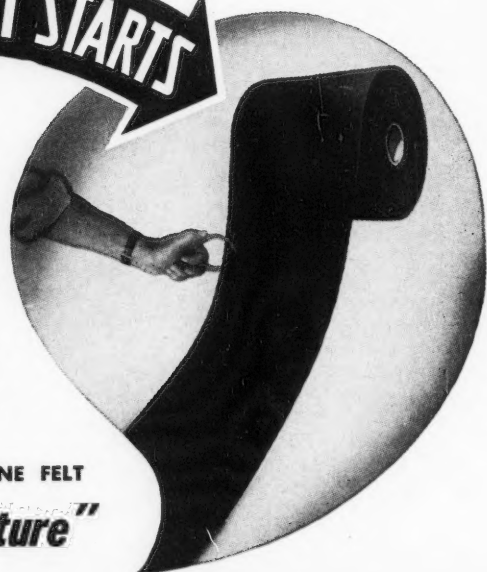
"the felt with a future"

*FORMERLY GAMA

The Felt With a Future

MANUFACTURED BY:
NICOLET INDUSTRIES, INC.
FORMERLY GAMA INDUSTRIES, INC.
70 Pine Street
New York 5, N. Y.

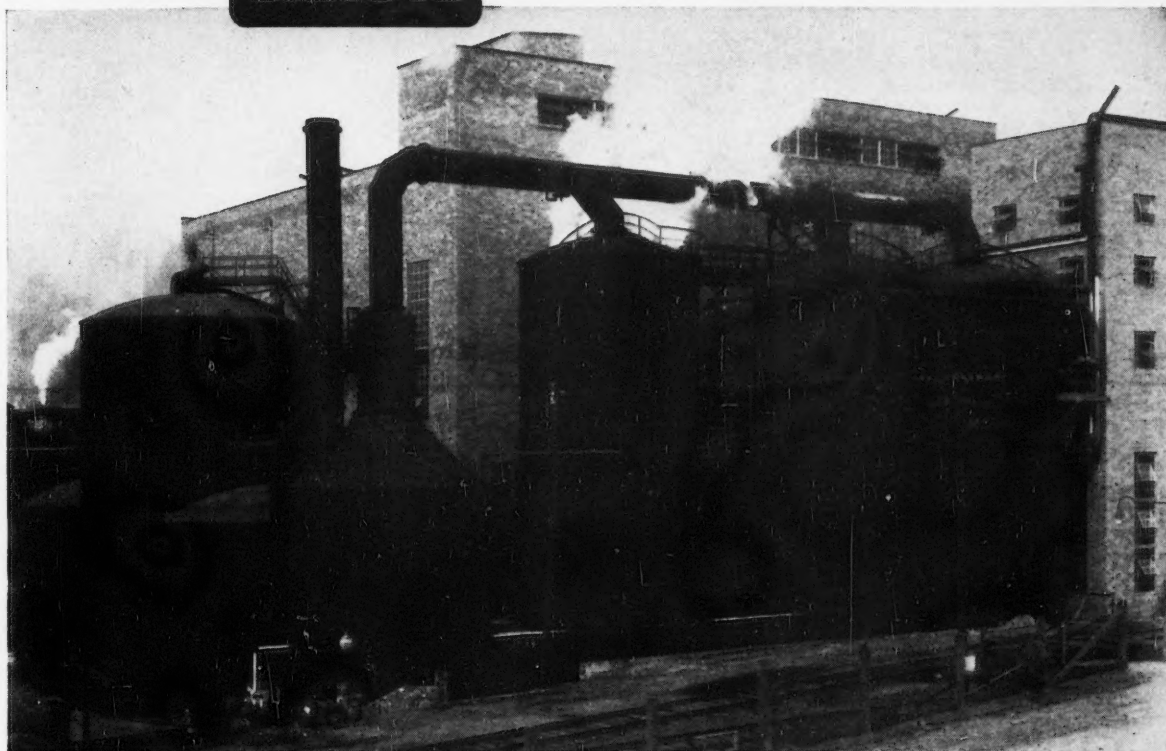
DISTRIBUTED BY:
MIDDLE WEST COATING & SUPPLY
207-A Daniel Bldg. Tulsa, Okla. Ph. 2-5215
P. O. Box 153 or 2-5216



ANOTHER

ERKOTE

APPLICATION OF MASTIC COATING



ERKOTE Mastics give you more than appears on the surface!

"3-in-1 Protection" makes every job our responsibility

Since we develop and produce our own mastics and paints and furnish our own trained crews to apply and maintain ERKOTE products, we assume *full responsibility* for the quality of the materials and the workmanship on every job we undertake. Development . . . manufacture . . . application . . . you get *all three* from *one reliable source*!

That's why more and more industries are using ERKOTE products for insulating, weatherproofing and protection against corrosion.

You get impartial advice

Because we manufacture both mastics and paints for industrial protection, we can supply the exact coating to satisfy your requirements. Our engineers will be glad to help you with our recommendations.

Earl Paint Corporation • 240 Genesee Street • Utica, N.Y.

Sales Offices: Houston, Philadelphia, Baltimore, Pensacola

ERKOTE
TECHNICAL
COATINGS

FOR USE WHERE PAINTS FAIL

ERKOTE PRODUCTS

Corrosion Resisting Mastics, Mica Mastics, Insulating Mastics, Vapor Seals, Troweling Mastics, Color Finishers, Industrial Paints and Varnishes.

NEW PRODUCTS — Materials — Service — Literature

Anaconda Tubes and Plates for Condensers and Heat Exchangers, a new and expanded edition, profusely illustrated, is available from The American Brass Company, Waterbury 20, Conn. The bulletin is designated Publication B-2. Contents include applications of condenser and heat exchanger tubes, alloys, plates, manufacturing methods, installation data, operational factors affecting tube life, corrosion factors in condenser tube service, physical properties and working stresses and other information on the company's products.

Cells converting atomic energy directly into electrical energy designed by Philip E. Ohmart of Ohmart Corporation, Cincinnati are being used by the firm as a power source for a line of instruments designed to precisely measure gamma activity. Because they require no high voltage power supply, and have only one tube, and since the energy in the radioactivity itself is used to produce the electrical current, the manufacturers state the instruments have unusual simplicity and make possible 4-pi geometry by inserting samples within the cells. Additional instruments using the principle are contemplated by the firm.

Blowers of polyester resin reinforced with glass fibers are being used in Westinghouse totally enclosed motors to replace metal blowers. Many advantages over the aluminum and bronze blowers formerly used are claimed, including resistance to chemical agents that attack the metals. The plastic blower is one third lighter than its metal counterpart and has satisfactory performance characteristics otherwise.

Tenite, Eastman cellulose acetate butyrate plastic is described in two publications of Tennessee Eastman Company, a division of Eastman Kodak Company, Kingsport, Tenn. "The Use of Tenite to Combat Corrosion in Piping Systems," an illustrated manual describing the uses, manner of installation, jointing procedure and working characteristics tells how Tenite piping is installed for transporting corrosives at low pressure. Illustrations show the material being used for salt water lines from oil wells. The publication "Tenite Specifications," gives detailed information on the formulas, classifications of products, color groups, sample policy, physical characteristics and a table giving resistance of Tenites I and II to 30 materials, including water, sodium chloride solutions, sulfuric and nitric acid solutions and others.

Tantalum materials for chemical operations are described and illustrated in a brochure "Fansteel Acid-Proof Tantalum Equipment for Chemical Operations," available on request from Fansteel Metallurgical Corp., North Chicago, Ill. The 28-page profusely illustrated booklet describes the physical characteristics of tantalum, its chemical and mechanical properties, resistance to reagents, types of equipment made from it, their uses and efficiencies. Bayonet, coil and double pipe heat exchangers are illustrated. Condensers for corrosive vapors, tubing and fittings, absorbers for hydrochloric acid, and pilot plant equipment are covered. The engineering service offered by the company is explained also.

Prufcoat Heavy-Duty Primer P-50, composed of heavy-bodied oil-modified

synthetic resin vehicle and a high percentage of inhibitive pigments, principally zinc chromate, is recommended by manufacturers, Prufcoat Laboratories, Inc., 50 East 42nd St., New York 17, for use on surfaces commonly found in process and other industrial plants. The material deposits a relatively heavy film which tends to level out rough surfaces and cover sharp edges. Overnight drying permits quick application of both conventional and active solvent top coats. Technical Bulletin Sheet No. 015 describing the primer is available on request.

Shell Chemical Corp. 50 West 50th St., New York, has opened a district sales office at Atlanta, Ga., with M. W. Ellison as manager.

Penn Metal Co., Inc., 205 East 42nd St., New York 17, has issued a 32-page catalog titled "Expanded Metal Meshes" which describes the expanded metal materials it fabricates. Of special interest are expanded aluminum, stainless steel, Monel, and Inconel provided in several meshes in both standard and flattened types. Uses of the expanded metal are illustrated and technical details about the flattening, bending, forming, heat treating, airflow comparisons and other useful pertinent information are included.

Haynes-Stellite Metal Cutting Tools are covered in a fully illustrated 44-pages-and-cover brochure available from Haynes-Stellite Company, a Division of Union Carbide and Carbon Corp., 30 East 42nd St., New York 17. The brochure describes the physical, chemical and mechanical characteristics of the principal tools manufactured by the company, gives resistance to corrosive media, information on metal cutting, tool grinding, brazing and the characteristics of basic bit shapes.

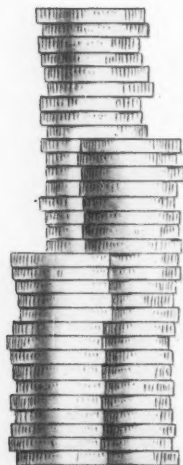
Swagelok Tube Fittings, a catalog of fittings manufactured by Crawford Fitting Company, 884 East 140th St., Cleveland 10, gives a detailed diagrammatic explanation of the operation of the fitting which has the faculty of not transmitting torque to tubing. The fittings are manufactured in a wide variety of sizes and shapes in brass, aluminum, steel, stainless steel and Monel. The catalog illustrates types of fittings and lists available sizes and combinations.

"**Lead**" No. 5, Vol. 18, available from Lead Industries Association, 420 Lexington Ave., New York 17, includes the following articles: Lead's part in Phonograph Record Manufacture, Bonded and Cast Lead Featured in New Vacuum Filters.

Shell Chemical Corp. expects to have operating in mid-1952 a 13,000-ton sulfur recovery plant at Houston which will extract sulfur from waste refinery gases. The output will be sold for conversion to sulfuric acid.

(Continued on Page 24)

PROFITS ARE SAVED NOT MADE



Whether it be a gas or water distribution system, a transmission pipe line, tank bottom, off-shore drilling platform, condenser or water tank, or ship hull, corrosion losses can be stopped—can be converted to profits.

Electro Rust-Proofing services are designed to help you make these savings. First, ERP offers a complete engineering service on either a contract or per diem basis to suit your individual needs. All survey and design work is conducted by qualified cathodic protection engineers fully equipped with the necessary precision measuring instruments and other testing apparatus. Second, ERP's Contract Department is available to furnish, install and maintain all cathodic protection equipment and materials which may be required.

Whether your company has a single tank or thousands of miles of pipe line, you'll find that ERP can help you save profits. Write for details without obligation, of course.

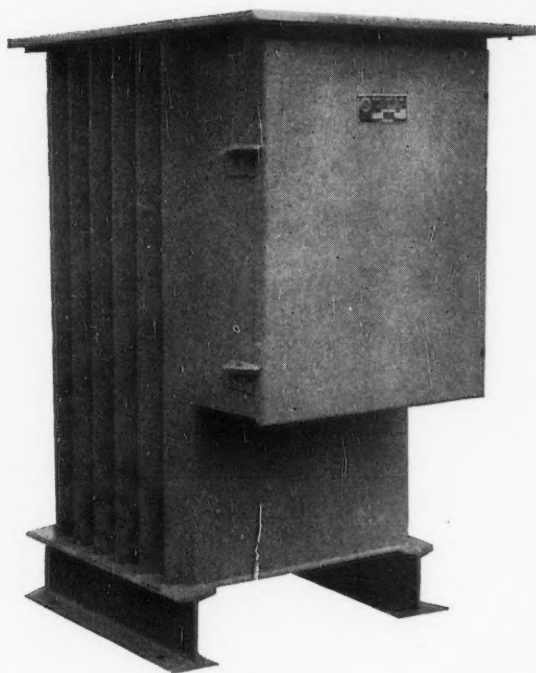
REPRESENTATIVES IN PRINCIPAL CITIES

Electro Rust-Proofing Corp. (N. J.)
BELLEVILLE 9, N. J.

E-16

CATHODIC PROTECTION FOR ALL BURIED AND SUBMERGED STRUCTURES

Brance-Krachy-FOR COMPLETE CATHODIC PROTECTION EQUIPMENT



**Specify
BRANCE-KRACHY RECTIFIERS
FOR LONG - TROUBLE-FREE LIFE!**

**LEADERS IN CATHODIC
PROTECTION EQUIPMENT FOR
OVER 20 YEARS**

**A FULL SALES AND
ENGINEERING SERVICE
TO CONTROL ANY TYPE
OF CORROSION PROBLEM**

WE INVITE YOUR INQUIRY

* RECTIFIERS

Brance-Krachy selenium, oil-immersed and convection cooled types.

* FEDERATED METALS

Magnesium and Zinc Anodes

GRAPHITE ANODES

National Carbon Co.

COKE BREEZE

Brance-Krachy Coal Coke
National Carbon Co. types

* PIPE COATING

Duratex

WIRE AND CABLE

Brance-Krachy Special
Cathodic Protection Cable

WRAPPING TAPE

POLY-TAPES (BUTYL
RUBBER)

Scotch No. 21, 22 and 33
U.S. Korona Splicing Compound

INSULATING MATERIAL

* Exclusive with Brance-Krachy

PIPE LOCATORS

M-Scope, Wahlquist and Detec-tron

"PLICO" PIPE LINE INSULA-TORS

Skids and Clamps. All Types

WELDING AND SOLDERING EQUIPMENT

Cadwell Welding Material
Prest-O-Lite Sets
Prepo Torches

MEASURING INSTRUMENTS

B-K Vibrogrounds for soil resistance

M. C. Miller multi-combination meters, soil boxes, current interrupters, copper sulfate electrodes

B-K Model 22 Potentiometers
Sheppard Potentiometers

HOLE DIGGERS

Hugh B. Williams models and McCulloch Earth Drill and Saws



Brance-Krachy Co. INC.

4411 NAVIGATION • P.O. Box 1724 • HOUSTON

FOR FULL INFORMATION, WRITE, WIRE OR TELETYPE (HO-561)

4411 Navigation Blvd., P. O. Box 1724, Houston; California—1036 Brent Ave., So. Pasadena, Calif. PYramid 1-2308. Oklahoma—321 1/2 Johnson St., Bartlesville, Okla. Phone 5798.

NEW PRODUCTS

(Continued from Page 22)

Non-Ferrous and stainless steel fastenings manufactured by H. M. Harper Company, 8200 Lehigh Road, Morton Grove, Ill., are covered in a 56 page

**PROVEN
CHEMICAL RESISTANT
LININGS**
to Fit the Job!

**For TANKS,
VESSELS,
PIPE,
Etc.**



**SELECTED
FOR
Long Life
AND
TROUBLE-FREE
SERVICE**

•RUBBER •KOROSEAL
•HEILEX •LEAD
•SPECIAL METALS

Heil PROCESS EQUIPMENT
CORPORATION
CLEVELAND 11, OHIO

price list and stock book available on request from the company.

Rub-Bub Caulk, a chromated caulking compound that stays pliable over extended periods, is recommended for use in places subject to rust by the manufacturers, Samuel Moore Chemical Co., Inc., Mantua, Ohio.

Technical Microcard Publishing Corp., 112 Liberty St., New York 6, N. Y., is prepared to reproduce research reports and other data on 3 by 5 inch cards. Each card will accommodate up to sixty letter-sized pages. One hundred cards occupy one inch of file space. A small portable device is used to magnify each page to its original size for reference.

Hysol is the name of a broad line of plastisols and organosols now being manufactured by Houghton Laboratories, Inc., Olean, N. Y.

Permolate pigmented organic corrosion resistant coatings are explained in a six-page folder available on request from the company's Hamilton, Ohio, offices.

Welded Fittings for corrosion resistant coated pipe are now possible through the use of Welstrom fittings. The fitting consists of three parts: An internal sleeve and two external fittings. The external fittings are welded to pipe ends and both are covered with corrosion resistant coating. The sleeve is then inserted into the fittings which are butted together, then welded. Through a threaded opening in the Welstrom fitting cold setting compound is introduced into the interior to repair the coating destroyed by the welding and then the opening is sealed with a pipe plug. This system permits welding internally coated pipe and provides a joint fully flush on the inside, fully coated with corrosion resistant material. An illustrated bulletin describing the system can be obtained from the manufacturer, Welstrom, Fifth St., North Ford Blvd., Hamilton, Ohio.

Silicone Rubber O-rings moulded by Frederick S. Bacon Laboratories are made in special dies allowing for the higher shrinking factor of silicone rubber. Technical Data Sheet No. 102 can be secured from Philip Wilkinson, Bacon Laboratories, 192 Pleasant St., Waretown, Mass.

Data From the files of Development and Research Division of International Nickel Co., Inc. 67 Wall St., New York 5, N. Y. on high temperature application of metals and alloys is available to metal users who are: 1. Undertaking a new process with which they have not had operating experience, involving corrosion at high temperatures. 2. Desire to compare performance to be expected from other metals and alloys with that of materials previously used and found unsatisfactory. 3. Require a substitute for an alloy or materials at present not readily available. A work sheet or questionnaire designed to facilitate inquiries is available on request.

PERSONALS

Robert G. Gerstmyer has joined Dearborn Chemical Company's sales staff to cover North and South Carolina with headquarters at Charlotte, N. C.

Owen R. Rice has been named vice-president and manager of Freyn Engineering Dept., engineering and construction division of Koppers Co., Inc.

R. P. White has been named manager of H. C. Price Co. coating operations in 37 states east of the Rocky Mountains. **H. N. VerSoy** has been named manager of Somatic's Gulf Coast Division, with **Leo C. Carle** as assistant manager. **Montie J. Lane** becomes East Coast Division manager, with **Troy L. Huitt** as assistant and **C. V. Johnson** in charge of sales.

George Russel Carr, chairman of the board of Dearborn Chemical Company, was honored in October on completion of a half century of continuous service with the company.

Adger S. Johnson has been appointed president of National Carbon Company, a division of Union Carbide and Carbon Corp.

Louis Lippha has been named treasurer and vice-chairman of the board of directors of Apex Smelting Co., Chicago. **Robert K. Beck** will be general manager of all operations, **Fritz Nussbaum** is new manager of raw materials purchases. **A. J. Peterson** has been promoted to vice-president in charge of sales and advertising with headquarters in Chicago.

Lloyd R. Jackson has been named assistant director of Batelle Institute, Columbus, Ohio.

Ben N. Youngken, retired sales manager of California Division, The National Supply Co., died at his home at Los Angeles October 1. He retired in 1942 after 43 years with the company.

Gives you a quick, easy method of determining what metal alloys to use in connection with 143 different corrosive agents. Ideal for metallurgists, product designers, engineers, chemists, purchasing agents. Sized to fit your pocket. Developed by The H. M. Harper Co., America's leading specialist in non-ferrous and stainless fastenings.

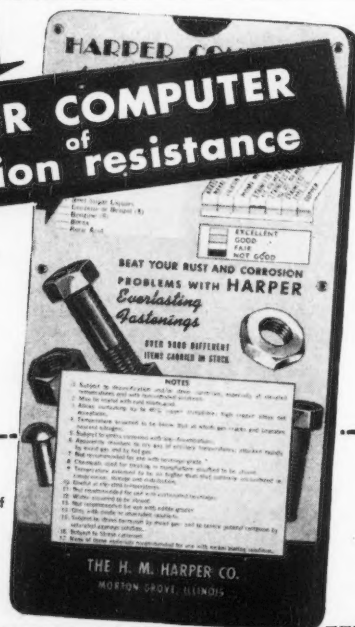
**FREE
MAIL COUPON TODAY!**

Chief Metallurgist,
The H. M. Harper Co.,
8221 Lehigh Avenue, Morton Grove, Ill.
Please rush my free copy of the Harper Computer of Corrosion Resistance.

Name.....
Company.....
Address.....
City..... State.....

SEND FOR
YOURS TODAY!

HARPER COMPUTER
of
corrosion resistance





Corrosion Abstracts

Index to CORROSION ABSTRACTS

Vol. 7	December, 1951	No. 12
GENERAL		
2. Importance	245a	Page
5. Directories	246a	
6. Books	246a	
7. Organized Studies	246a	
TESTING		
1. General	246a	
2. On Location Tests	246a	
3. Laboratory Methods	246a	
4. Instrumentation	251a	
CHARACTERISTIC CORROSION PHENOMENA		
6. Electrochemical Effects	252a	
7. Metallurgical Effects	252a	
CORROSIVE ENVIRONMENTS		
6. Water and Steam	254a	
PREVENTIVE MEASURES		
4. Non-Metallic Coatings and Paints	256a	
6. Packaging	260a	
7. Treatment of Medium	260a	
9. Surface Treatment	260a	
MATERIALS OF CONSTRUCTION		
4. Non-Ferrous Metals and Alloys — Light	260a	
5. Metals-Multiple or Combined	263a	
6. Non-Metallic Materials	263a	
7. Duplex Materials	264a	
EQUIPMENT		
1. Engines, Bearings and Turbines	264a	

(Complete Topical Index used in this section will be found in this issue in Index to Technical Material 1951.)

* PAGINATION OF CORROSION ABSTRACTS

Two numbers appear on each page of Corrosion Abstracts. The number in the upper outer corner is for page sequence within the issue only. The number in the lower outer corner, which is followed by the letter "a," denoting "abstracts," is for the convenience of those who bind Corrosion Abstracts by volumes. Because both numbers appear on each page and because it is believed indexing by the volume serial number will be more useful, the "Index to Corrosion Abstracts" is keyed to the number in the lower outer corner of each page followed by the letter "a."

GENERAL

• Importance

1.2.5, 6.3.2

Safeguarding Against Cadmium Poisoning. *Mech. World. Eng. Record*, 127, No. 3302, 476 (1950) Apr. 28.

A brief outline of the dangers of cadmium poisoning caused either by swallowing the metal or inhaling dust or fumes. The symptoms are noted, as well as the immediate treatment to be applied. Adequate ventilation and proper use of respirators are recommended preventive measures. It is also suggested that workers should wash thoroughly and change before leaving the factory, after working at potentially dangerous occupations. Foods should never be allowed in contact with cadmium or cadmium plated materials.—ZDA.

1.2.5, 5.9.2

Health Hazards in Metal Degreasing. PAUL W. McDANIEL. *Metal Prog.*, 58, No. 1, 77-78+ (1950).

The various kinds of health hazards originating from different methods of degreasing—alkaline cleaning, acid cleaning, solvent degreasing—are discussed, and protective measures recommended.—MA.

1.2.5

Lead Poisoning. *Naval Aviation News*, No. 305, 18-20 (1950) May.

The dangers of lead poisoning to jet pilots and maintenance personnel working on jet engines are pointed out. The health hazard stems from the use by the Navy of ethylated gasoline as jet

PRIMARY SOURCES OF ABSTRACTS PUBLISHED IN CORROSION

AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Ontario, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BLR—Battelle Library Review, Battelle Memorial Institute Library, 505 King Ave., Columbus, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association, 81-91 Euston St., London NW1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating, 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California, 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum, 26 Portland Place, London W#1, England.

MA—Metallurgical Abstracts, Institute of Metals, London, England, 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana, Associazione Italiana di Metallurgia, Via S. Paolo, 10, Milano, Italia.

MR—Metals Review, American Society of Metals, 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards, Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

PDA—Prevention Deterioration Abstracts, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers, 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France, 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London, Waldegrave Rd., Teddington, Middlesex.

TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio.

TIME—Transactions of Institute of Marine Engineers, 85 The Minories, London EC 3, England.

UOP—Universal Oil Products, 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association, Lincoln House, Turl Street, Oxford, England.

Sources of PHOTOPRINTS and/or

MICROFILM COPIES

of Technical Articles Abstracted in

CORROSION ABSTRACTS

ENGINEERING SOCIETIES LIBRARY,
29 West 39th Street, New York 18,
N. Y.

CARNEGIE LIBRARY OF PITTSBURGH,
4400 Forbes St., Pittsburgh 13, Pa.

NEW YORK PUBLIC LIBRARY, New
York City.

U. S. DEPT. OF AGRICULTURE
LIBRARY, Office of Librarian, Wash-
ington, D. C. (Special forms must be
secured).

LIBRARY OF CONGRESS
Washington, D. C.

JOHN CRERAR LIBRARY
86 East Randolph St.,
Chicago 1, Ill.

Persons who wish to secure copies of
articles when original sources are un-
available, may apply directly to any of
the above for copies. Full reference in-
formation should accompany request. The
National Association of Corrosion Engi-
neers offers no warranty of any nature
concerning these sources, and publishes
the names for information only.

NACE will NOT accept orders for
photoprint or microfilm copies of material
not published by the association.

fuel for carrier-based attack airplanes. The clinical diagnosis of incipient lead intoxication is most difficult until fairly clear-cut symptoms are manifested. The so-called "lead line" on the gums is seldom seen on personnel with good mouth hygiene and is unreliable at best. The value of blood and urine examinations by themselves is also dubious. There appears to be general agreement that the history, symptoms and a consideration of the entire blood picture are necessary before establishing the diagnosis of lead intoxication. General safety measures are discussed, such as repeated washing of the hands, cleaning of the shops with vacuum cleaners and periodic blood examinations. Line personnel are warned not to come within 50 ft. of an operating jet exhaust nor too close to a hot tail pipe.—TDD.

• Directories

1.5

Materials Selection Chart. N. S. MOTT. *Chem. Eng.*, 57, 197-200 (1950) Aug.

Chart lists common industrial chemicals and materials in alphabetical order. Degree of resistance to corrosion by each material of carbon steel; stainless Types 304, 316, and FA-20; and a few nickel alloys is indicated qualitatively.—BLR.

• Books

1.6, 3.5.9

Metals at High Temperatures. FRANCES HURD CLARK. 372 pages. 1950. Reinhold Publishing Corp., New York.

A compilation of recent available data on the properties of the above. Includes a theoretical discussion on plasticity and a section on test methods and manufacturing methods for heat-resistant alloys. Includes diagrams, photographs, micrographs, graphs, numerous tables and extensive chapter bibliographies.—BLR.

• Organized Studies

1.7.1, 4.1, 5.4.5

Protection of Iron Against Atmospheric Corrosion by Means of Paint. II—Tables and Graphs. Centraal Instituut Voor Materiaalonderzoek, Afd. Corr., No. 26, Pt. II, 69 pp. (1949).—RPI.

1.7.2

Corrosion Testing Station to Open in North Carolina. *Am. Metal Market*, 57, No. 202, 3 (1950) Oct. 21.

The new Harbor Island addition to the Kure Beach corrosion testing project near Wilmington, N. C., will be formally opened on November 15 and 16. The facilities of the project have been expanded to accommodate over 20,000 specimens of all types of materials in sea water and sea air. The sea water tests which were established at Kure Beach in 1935 have been moved 20 miles north to Harbor Island, but the atmospheric testing lot and shore station about 80 feet from the shoreline have been retained at Kure Beach. The corrosion testing project, which is one of the largest in the world, is operated under the direction of the International Nickel Co., but numerous manufacturers cooperate to obtain corrosion data.—ALL.

1.7.1

Fundamental Corrosion Research. Work of the Thermodynamics and Electrochemical Kinetics Committee. (In French). M. POURBAIX AND P. VAN RYSELBERGHE. Preprint, U. N. Sci. Conf. on Conservation and Utilization of Resources, Lake Success, N. Y., Aug. 17-Sept. 6, 1949. 6 pp.

The corrosion research program of the International Thermodynamics and Electrochemical Kinetics Committee is outlined.

1.7.1, 6.4.2

Report of ASTM Committee B-7 on Light Metals and Alloys, Cast and Wrought. *Am. Soc. Testing Mat. Preprint*, No. 13, 12 pp. (1950).

Revisions are proposed of the following nine tentative specifications: (i) aluminum-base alloy sand castings, (ii) aluminum-base alloys for permanent-mold castings, (iii) aluminum and aluminum alloy sheet and plate for use in pressure vessels, (iv) aluminum-base alloys in ingot form for sand castings, die-castings, and permanent-mold castings, (v) aluminum and aluminum alloy sheet and plate, (vi) aluminum alloy drawn seamless tubing, (vii) aluminum alloy drawn seamless tubes for condensers and heat-exchangers, (viii) aluminum alloy extruded tubes, and (ix) aluminum alloy pipe. A new tentative specification for aluminum alloy die-forgings is given. This includes tables of the required chemical compositions and mechanical properties of the eleven alloys specified, with relevant details regarding sampling methods of testing.—MA.

1.7.1, 2.2.2, 6.3.19, 6.4.4

Report of ASTM Committee B-6 on the Corrosion of Die-Cast Metals and Alloys. *Am. Testing Mat.*, Preprint, No. 12, 6 pp. (1950).

Besides making recommendations for revisions of specifications, this report includes a table giving the mechanical properties (tensile strength, elongation, impact strength, hardness) of sixteen zinc-base and twelve magnesium-base die-cast alloys after exposure for ten years at five outdoor and three indoor sites.—MA.

TESTING

• General

2.1.2, 2.2.2

Technique and Evaluation of Results in Paint Exposure Testing. K. R. BUSSELL. *Paint Notes* (Australia), 5, No. 7, 191-199 (1950) July.

This paper describes modifications and extensions, made in the light of experience in the technique of paint exposure testing outlined previously. The new method of evaluation takes account of discoloration; this is done by comparing exposed and unexposed paint films of equal age. It is said that individual operators have achieved consistent results in assessing degrees of chalking by the "finger-on-velvet" method. The author mentions that sometimes failures visibly rated as erosion appear as fine-flaking under the microscope. A typical life history of a paint film is chosen to illustrate the interpretation of exposure results in a simple manner.—ZDA.

• On Location Tests

2.2.2, 5.4.5

Exposure Testing. *Paint Technol.*, 15, No. 175, 287-290 (1950) July.

This critical examination of exposure test procedure is illustrated by faintly humorous drawings. The author points out the important effect which weather conditions at the time of painting have on paint performance and suggests that during the whole period of an exposure test, the weather may be very different from the mean. In practice, paint is applied on a variety of surfaces and facing different directions. It is suggested that reports from actual users should be employed to check results obtained from exposure tests. He discusses the choice of sites and the keeping of adequate weather records, and concludes by stressing the value of repeat tests, carried out at the same sites, but under different weather conditions.—ZDA.

2.2.3, 6.2.5, 2.3.2

Results of Some Plant Corrosion Tests of Welded Stainless Steels. GEORGE F. COMSTOCK. *Am. Soc. Testing Materials*, "Symposium on Evaluation Tests for Stainless Steels," Special Tech. Publ. No. 93, 1950, 200-209+.

Corrosion tests were made in chemical plants under regular operating conditions and results compared with those obtained by the standard boiling nitric acid procedure. Specimens included Types 304, 321, and 347 sheets, welded with Types 308, 321, and 347 electrodes, respectively, and tested both in as-welded and stress-relieved conditions. Results are tabulated and show no correlation.—BLR.

• Laboratory Methods

2.3.2, 5.5.1

A Symposium on the Testing of Temporary Corrosion Preventives. *J. Inst. Petroleum*, 36, 422-473 (1950) July.

Consists of the following papers: "The Nature and Scope of Temporary Corrosion Preventives," D. Clayton and M. C. Thompson; "Assessment of the Protective Value of Temporary Corrosion Preventives (With Particular Reference to Humidity Cabinet Tests)," T. G. Clinton; "Use of Weatherometer and Humidity Cabinets for Evaluation of Temporary Corrosion Preventives," W. Pohl; "A Method for the Evaluation of Soft-Film Temporary Corrosion Preventives for Ferrous Articles," T. P. Hoar and G. C. Smith; "Application of an Accelerated Atmospheric Corrosion Test to the Assessment of Temporary Corrosion Preventives," R. St. J. Preston and E. G. Stroud; and "Tests of the Protective Value of Temporary Corrosion Preventives on Steel," S. G. Clarke and E. E. Longhurst.

2.3.2, 5.4.5, 4.6.11, 4.1

A Method of Selecting Protective Coatings for Offshore Drilling Structures. JACK P. BARRETT. *Corrosion*, 6, No. 11, 376-381+ (1950) Nov.

Describes laboratory testing program set up to evaluate protective coatings. To further verify the laboratory results, panels coated with the various painting systems were exposed at a marine location in the Gulf Coast. Correlation was

PROBLEM:

HCL fumes were causing serious corrosion of pipes and structural steel as well as disintegration of the poured concrete walls and ceiling areas in the galvanizing department of a New England mill.

SOLUTION:

Two coats of Prufcoat #1120 over a spot prime coat of the same material were applied in April 1948. With corrosion controlled and disintegration stopped, repainting was not necessary until April 1951.

Where Acids or Alkalies Destroy
Prufcoat **PROTECTS**

Hydrochloric Acid Fumes
in Galvanizing Department



NEW!
Prufcoat
Metal-Reactive
Primer P-10

Does not require as complete surface cleaning as most other priming methods and works well on damp or dry surfaces. Makes possible a simple yet positive two-step system for corrosion-proofing old or moist metal surfaces. Write today for Prufcoat Technical Bulletin 012.



... "Prufcoat has taken the job of protecting the metal and masonry in our galvanizing department out of the jinx job classification," the engineer in charge of this plant recently reported . . . "Before we Prufcoated our galvanizing department, we were forced to repaint this area every year and it looked as though it had never been painted after only six months."

Yes, performance records *prove* that where acids or alkalies destroy, *Prufcoat Protects* . . . on concrete floors, walls, ceilings, structural steel, pipes, tanks, ducts, machinery and equipment.

Coat for Coat, Prufcoat Gives More Protection
at Lower Cost Than Any Other Air-drying Paint

Economical in original cost as well as in the preventive maintenance terms of positive protection against costly corrosion, Prufcoat Protective Coatings come ready-to-use in single, five and 55 gallon containers and are available in a wide range of attractive colors including green, buff, black, red, white, and several shades of gray.

An experienced Prufcoat corrosion engineer will gladly make a Preventive Maintenance Survey of *your* plant. No obligation, of course. *Write today, describing YOUR corrosion problems.*

PRUFECOAT LABORATORIES, INC.
50 East 42nd Street, New York City

Preventive Maintenance PAYS

about 90 percent. Some 30 systems have been tested to date and approximately 60 percent were totally unsuited for the conditions involved. 20 percent were of doubtful value leaving 20 percent that could be used with more or less effectiveness.—BLR.

2.3.2, 4.2.7

Materials and Finishes for Tropical Service. C. D. COOK AND C. MERRITT, JR. *Mat. and Meth.*, **25**, 77-80 (1947) May.

Discusses humidity-testing procedure. Tables give results of humidity and salt-spray tests on several metals with various types of surface finishes. Another summarizes the electrolytic behavior of certain materials.

2.3.2, 4.4.9, 4.4.6

The Copper-Strip Test—A Study of Current Methods of Interpretation and an Examination of Proposed New Procedures. F. W. H. MATTHEWS AND D. F. PARSONS. *Proc. Am. Petroleum Inst. (Refining Div.)*, **30M** (III), 24-36+ (1950).

IP and ASTM methods for evaluating the corrosive properties of oils by means of the copper-strip test are discussed with respect to difficulties met with in classifying tarnished strips by the color produced a new method, designated the "cathodic-reduction" method, is described which provides a rapid analysis of the film on a tarnished copper strip. Cupric and cuprous sulfides and oxides may be distinguished and estimated. Action of peroxidic "inhibitors" of corrosion, relation between "corrosive" sulfur in the material and sulfur on the strip, and effect of "free" or "elemental" sulfur in the presence of other sulfur compounds were also investigated.—BLR.

2.3.2, 5.5.3

Assessment of the Protective Value of Temporary Corrosion Preventives (with Particular Reference to Humidity Cabinet Tests). T. G. CLINTON. *J. Inst. Petroleum*, **36**, 428-435 (1950).

Factors that are likely to produce breakdown of temporary corrosion preventives under conditions of service are discussed, and certain performance tests applicable to the evaluation of the protective qualities of these coatings are considered. The use of a humidity cabinet and an intermittent salt-spray test are described in detail. Accelerated weathering, continuous salt-spray, and natural weathering tests are described. There is at present no single performance test that is likely to forecast the behavior of protectives under all conditions of service.—PR.

2.3.2, 5.5.3

Tests of the Protective Value of Temporary Corrosion Preventives on Steel. S. G. CLARKE AND E. E. LONGHURST. *J. Inst. Petroleum*, **36**, 463-473 (1950).

The authors present results of corrosion tests made by relatively simple methods. Free exposure to the outdoor atmosphere, the ARE salt-spray test and a non-streaming humidity test were found to give comparable orders of merit for several protective coatings on steel. Outdoor exposure is in general too severe and too variable for testing oil films. A sprayed-on water-droplet test discriminated between oil films. Increasing the film weight of lanolin gave increasing protection in an outdoor test. A marked reduction in the weight of steel oxidized in the ARE salt-spray test was found when extremely thin oil films were used.—PP

2.3.2, 3.5.8

Rapid Stress-Corrosion Tests. (In German.) F. C. ALTHOF. *Metall.*, **4**, 267-273 (1950) July. *Metals Rev.*, **23**, No. 11, 40-41 (1950) Nov.

Experiments were made to test the validity of two proposed rapid tests for sensitivity of aluminum-zinc-magnesium alloys to stress-corrosion. One test uses synthetic sea water at 70° C, the other a 1 percent sodium chloride solution at 100° C. Results fail to agree with those obtained from long-time tests. Shows that tensile tests made in corrosive media at room temperature indicate susceptibility to stress-corrosion sufficiently well to be of practical value.—INCO.

2.3.2, 6.4.2

Amalgamation of Aluminum and Its Alloys in the Presence of Water. (In Czech.) FERDINAND KRALIK. *Hutnické Listy*, **5**, 326-328 (1950) Aug.

Discusses influence of the liquid mercury phase on spontaneous disintegration of amalgamated aluminum. This effect is said to be specially important in aluminum-zinc-magnesium and aluminum-zinc alloys. Shows how the effect can be used to determine the susceptibility of the alloys to inter-crystalline corrosion, and for detection of harmful internal stresses.—BLR.

2.3.5, 5.4.8

Underwater Paint for Steel Ships. I—General. II—Active Protection by Pigments. E. JIMENO, S. MEDION-CASTELLANOS, AND J. ARAYIO-TORRE. *Inst. españ. oceanog.*, Notes y resúmenes, Ser. II, No. 139, 16 pp. (1947). *Bol. inst. españ. oceanog.*, No. 25, 39 pp. (1950).

I—A general discussion and review with 17 references. II.—Difference between the electrode potential against sea-water of a painted and unpainted iron plate gives a measure of the mechanical protection (because of impermeability) provided by the paint. The potential of a plate painted in stripes, so that portions of unprotected iron are in contact with sea-water, gives a measure of the "active" protection due to the nature of the pigment. There were some discrepancies in the results of potential determinations and of microscopic examination of the corroded surfaces. Determination of potentials affords a useful supplementary test for the protective value of a paint, but is not reliable as a sole test.—RPI.

2.3.5, 8.9.3, 7.2, 4.5.1

How Gulf Pipe Line Locates "Hot Spots" on Crude-Oil Line. M. C. CALLAHAN, Gulf Refining Co. *Oil Gas J.*, **49**, No. 20, 312+ (1950) Sept. 21.

Surface-potential method is used frequently in locating corrosive areas of pipe lines. Soil-resistivity measuring devices are used in conjunction with pipe-to-soil potentials as a proof check of corrosive hot spots.—INCO.

2.3.5, 5.2.4

A New Method of Measuring Potentials of Polarized Electrodes in Soil Corrosion Cells. W. NEIGHBOURS. *New Zealand J. Sci. Tech.*, **30**, No. 201 (1949) Jan.

A method is described in which the current through a soil-corrosion cell can be interrupted and the potentials of the polarized electrodes during the interruption can be measured.

2.3.5

Investigation of Oxidation and Corrosion Processes on Metal Surfaces With

the Aid of Voltage Measurements. (In German.) H. NEUERT AND H. HANSEL. *Z. für angew. Physik*, **2**, 319-323 (1950) Aug. 15.

Using Kelvin's method and gradual voltage changes on the surfaces of aluminum, Duralumin zinc, iron and lead, it was found that aluminum and Duralumin undergo strong and characteristic changes. Shows that this method can be used to study the resistance of metals to gaseous corrosion. Test results obtained in an acid-vapor atmosphere agree with known corrosion behavior of the respective metals.—BLR.

2.3.5, 5.9.2

Contribution to the Study of Electropolishing. (In French.) R. AUDUBERT, M. BONNEMAY, AND E. LEWARTOWICZ. *J. des Recherches du Centre National de la Recherche Scientifique*, No. 12, 139-147 (1950).

Mechanism of electropolishing was investigated with emphasis on the study of anodic overvoltage. The experimental work was done on electropolishing of stainless steel. Method of investigation is described. Data are tabulated and charted.—BLR.

2.3.6

Method of Measuring Surface Polish. A. MIRAU. *Rev. Opt.*, **29**, 25-26 (1950).

Light from a point source is reflected or refracted at the test surface and brought to an approximate focus; beyond the focus is a photocell. The diffused light and total light are measured respectively with and without a small stop covering the geometrical image. The ratio indicates the degree of polish. The method is convenient for small or inaccessible surfaces; in the case of reflection from the inside of a cylinder it has been found sensitive when pits have a depth up to 3 μ .—MA.

2.3.6, 6.2.5

Identification of Structural Constituents of Stainless Steels. (In English.) J. C. JONGEBREUR AND G. VOLLERS. *Metallen*, **4**, 247-259 (1950) Aug.

Using a number of specimens of stainless steel, the reliability of various etching reagents and of a magnetic identification method was determined. Surveys stainless steels used in practice and describes their compositions. Includes diagram for examination of stainless steels, based on a survey of etching reagents and their potentialities. Numerous photomicrographs.—BLR.

2.3.7

Routine Measurement of Surface of Paint Pigments and Other Fine Powders. I. P. C. CARMAN AND P. LE R. MALHERBE. *J. Soc. Chem. Ind.*, **69**, No. 5, 134-143 (1950) May.

The authors describe the air permeability method for determining surfaces of paint pigments. A simplified technique may be used for routine control which avoids the difficulties caused by slip flow. Permeability surfaces were found to vary with porosity and results were compared with those obtained by low-temperature nitrogen absorption.—ZDA.

2.3.7

Testing the Wear Resistance of Surfaces. (In German.) H. MEINCKE. *Metall-oberfläche*, sec. A, **4**, 145-151 (1950) Oct.

Shows that frequently used methods of materials testing (such as hardness

testing) are unsuited to the measurement of wear resistance. Describes a method of testing wear-resistance as a suggestion for standardizing testing practices under comparable conditions. Equipment

is illustrated, and data are graphed and tabulated.—BLR.

2.3.7, 2.3.4, 5.4.5, 8.9.1

Methods of Evaluating Aircraft Primers. E. T. NELSON. *ASTM Bull.*, 167, 88-92 (1950) July.

A review of the methods used by the Douglas Aircraft Co. to test zinc chromate primers for aircraft and of the special properties required in such paints. Advantage is taken of the tolerances in the Air Force—Navy Aeronautical Specification AN-P-656 to meet some of the special requirements. Tests are described under the headings physical, film and resistance properties. In the discussion which followed the presentation of the paper the specification was widely criticized.—ZDA.

2.3.7, 3.5.8

Creep and Fatigue Testing Equipment in the Laboratories. J. McKEOWN. *Metallurgia*, 42, No. 251, 189-194 (1950) Sept. British creep and fatigue testing equipment and the techniques suitable for testing a wide range of nonferrous metals over a considerable range of temperatures are described. The use of multiple machines and simple methods of temperature control and of strain measurements has provided extensive creep testing facilities at a very moderate capital cost. Equipment of both fatigue and creep testing at room temperature and elevated temperatures up to 750 C is described. The elevated temperature equipment for creep testing can also be used for tests in which the specimen is

CORROSION-PROOF

LININGS CEMENTS BRICK

• TANKS, FLOORS, FUME DUCTS AND PROCESS EQUIPMENT
• COMPLETE LINE OF PROTECTIVE COATINGS..

Over a Quarter Century of Experience

CEILCOTE **CORROSION-PROOF**
MATERIALS • CONSTRUCTION • SUPERVISION

The CEILCOTE Co. 4832 RIDGE RD., CLEVELAND 9, OHIO

Write for Rates:
919 Milam Bldg.
Houston 2, Texas

CORROSION DIRECTORY

Over 4195 Readers
Receive Corrosion
Magazine Monthly

CORROSION ENGINEERING

Let us select and apply the coating or lining best suited to protect your equipment and structures.

A & P FINISHING & MFG. CO.
17760 Clarann Avenue
Melvindale (Detroit) Mich.

Corrosion Engineering Company

1814 Richmond Houston, Texas
JA-7222 KE-5136
ALLEN D. STAFFORD, President
Inquiries invited

Cathodic Protective Systems Designed and Installed

Coating and Laying Specifications;
Corrosion Surveys; Consultation On
All Types of External Pipe Line Corrosion.

Huddleston Engineering Co.
Bartlesville Oklahoma

Corrosion Proof

CEMENTS FLOORS LININGS COATINGS

Rely on Atlas' over a half century of service to help solve your problems.

Atlas **MINERAL PRODUCTS COMPANY**
MERTZTOWN, PA. HOUSTON, TEXAS

SERVING ALL PIPELINES

PIPELINE ASBESTOS FELT
Made by The Ruberoid Co.
COAL TAR ENAMEL COATINGS
Made by Pittsburgh Coke & Chem. Co.
PERRAULT GLASS PIPE WRAP
Made by Perrault Glass Fiber Corp.
"Steve" Day
S. D. DAY COMPANY
1973 W. Gray Houston 19, Tex.
Phone JU-2431

Complete Corrosion Mitigation
Product and Equipment Line
WE REPRESENT: Koppers Coatings, Nicolet
Asbestos Pipe Line Felts, Apex Magnesium
Anodes, National Graphite Anodes, Tapecoat.
• Rectifiers • Instruments
and other nationally known products
MIDDLE WEST COATING & SUPPLY
TULSA, OKLA.
207-A Daniel Bldg. Phone: 2-5215

Cathodic Protection Service

Engineering - Installation - Surveys
Material - Supplies

Everything in the Cathodic Protection Field from an Insulating Washer to a Turnkey Contract Installation

4601 Stanford - HOUSTON - Phone JA 5171
NEW ORLEANS TULSA
149 Metairie Lawn Dr. 310 Thompson Bldg.
Phone TE 5735 Ph. 2-9857

CARL G. DEUBER

Technical Services in
Prevention of Deterioration

Anaerobic Corrosion
Fungus Inertness Tests of Pipe Coatings -
Wrappers - Tapes

Laboratories
114 East 32nd Street Telephone:
NEW YORK 16, N. Y. LExington 2-3244

RIO ENGINEERING CO.

Cathodic Protection Systems

Surveys Installation Design

HOUSTON, TEXAS
3607 Yoakum KE 9792

INSTRUMENTS

For the Corrosion Engineer

- Copper Sulfate Electrodes
- Resistivity Rod & Pipe Prod
- AC Bridges
- No Current Potentiometer with Current Ranges

J. L. COLLINS
ANGLETON, TEXAS

CATHODIC PROTECTION

Surveys Engineering
Installation Maintenance

Electro Rust-Proofing Corp.
(N. J.)

BELLEVILLE 9, NEW JERSEY
Atlanta - Chicago - Dallas - Monrovia

PIPE COATING "KNOW-HOW"

by PIPE PROTECTION SERVICE, Inc.

Modern Portable Railroad
Equipment for Any Size Pipe or Job

Main Plant: 179 FRONT ST., ELIZABETH, N.J.
"The Complete Coating Service"

A. R. FOX Corrosion Engineering Service

Cathodic Protection - Non-Destructive Testing
Special Investigations
Miscellaneous Instruments & Supplies

3405 Piedmont Ave.
Oakland 11, Calif.

Complete CATHODIC PROTECTION

Systems . . . supplies . . . service
for special applications; water tanks
and pipe lines.

HARCO CORPORATION
16901 Broadway Cleveland, Ohio

South Florida Test Service

INSPECTION - TESTING - RESEARCH
ENGINEERS
(Established 1931)

Corrosion, weathering and sunlight tests.
Four locations in Southern Florida for inland,
salt atmospheric, tidalwater and total immersion
exposure tests.

4201 N. W. 7th St. MIAMI, FLORIDA

subjected to a constant load and the time to produce fracture is determined. The type of fatigue test described which applied a constant bending moment, is suitable for work on specimens of either rod or pipe.—TDD.

2.3.7

Strain-Indicating Enamels and Varnishes. S. KOHN, V. KARNOJITSKY, AND

Distributors & Contract

Applicators of:

AMERCOAT maintenance coatings and tank linings.

OSPHO, phosphoric-dichromate surface preparation.

CARLON plastic pipe.

OXYCHLORIDE, mineral cement tank floors and linings.

WE OFFER the following services in Texas and Louisiana:

I A GUARANTEED maintenance program on tanks and steel structures wherein a pre-determined cost extending over 9 or 12 years, averaging 4 cents per year, per square foot can be properly budgeted.

II TANK LINING service with fully proven protective linings for **Sour Crude, Acid Sludge, Run Down, Acid Storage, Caustic Storage and Floating Roof Tanks.**

III EFFECTIVE, and fully proven service on **LINING Tubular Goods, Treaters and Wash Tanks, Salt Water Disposal Pipe, Drill Tubing.**

CORROSION ENGINEERING CO.

Allen D. Stafford, Pres.

1814 Richmond Houston 6, Texas
Phones JA-7222—KE-5136

C. TAGUET. *Recherche aeronaut.*, **13**, 11-17 (1950).

When a piece of metal to which a properly formulated "varnish" or "enamel" has been applied suffers elastic-deformation to such an extent that the organic film cracks, the resultant cracks are perpendicular at every point to the directions of maximum extension. This thus affords a simple method of exploring the field from both qualitative and quantitative aspects in indicating the best place for positioning strain gauges. When the organic film is produced by fusing a solid resin on the warm metal surface it is termed an "enamel"; if it is produced by evaporation of a solution of a resin in a solvent it is called a "varnish." After consideration of the relevant physical, chemical, and physico-chemical aspects, methods for the preparation of satisfactory enamels and varnishes are described. These are based on colophony resins; the latter employing carbon disulphide as the solvent.—MA.

2.3.8, 4.3.5, 8.8.1

High-Rate Sulfur Melter. B. A. AXELRAD AND L. A. NELSON. *Freeport Sulphur Co. Ind. and Eng. Chem.*, **42**, No. 11, 2212-2215 (1950) Nov.

Description of the pilot plant research for commercial equipment and the commercial reclamation plant for the recovery of contaminated sulfur accumulated in the Frasch process. The tray of the sulfur feeder and the hopper were lined with aluminum plate and gave good service. Steel steam coils in the melting pit showed little, if any, attack but a steel strainer in the melting pit pump suffered severe internal corrosion at the air-sulfur interface.—INCO.

2.3.9

Study by Electron Diffraction of Certain Reactions and Surface Structures of Metals; The Method of Vacuum Casting. (Concluded.) ROBERT COURTEL. *Metaux & Corrosion*, **25**, 188-199 (1950) July-Aug.

Describes results of study of surface reactions during casting in a controlled

atmosphere. Describes general characteristics of oxidation reactions during casting for the cases of iron, aluminum and magnesium. Gives evidence for an "oxidation threshold," using an 80-20 nickel-chromium alloy as an example. Describes a second method for determination of temperature attained during casting. Finally, describes an application of vacuum casting to the problem of oxidation of rare-earth metals; and gives evidence of the existence of the "C" form of cerous oxide and data on its lattice constants. Presents resume of the entire article.—BLR.

2.3.9, 3.7.4, 6.2.5

Carbide Precipitation in Type 304 Stainless Steel—An Electron Microscope Study. E. M. MAHLA AND N. A. NIELSEN, E. I. duPont de Nemours and Co. Paper before ASM, 32nd Ann. Conv., Chicago, Oct. 23-27, 1950. ASM Preprint No. 16, 25 pp. (1950).

Electron photomicrographs of carbides isolated in an unchanged state from sensitized Type 304 stainless steel, by means of a solution of bromine in methanol, show size, form and distribution of the carbide precipitates (Cr_2C_6). The carbide precipitate undergoes an isothermal change in form in which the particles tend to assume more stable energy configurations with time at the sensitizing temperature. The sequence of transformation appears to be: Precipitation of dendrites \rightarrow growth of dendrites \rightarrow fragmentation of dendrites \rightarrow change to more stable geometric forms. No obvious correlation of carbide form alone was found with the standard nitric acid corrosion rates of the respective alloy specimens.—INCO.

2.3.9, 3.8.2

Relationship of the Reaction Mechanism of Atmospheric Oxygen to the Theory of Local Galvanic Corrosion. (In German.) G. BRINKMANN. *Werkstoffe u. Korrosion*, **1**, 217-232 (1950) June-July.

Describes experiments made to study the transfer of oxygen to metals (zinc, iron and aluminum) by way of activated carbon, oxidation of the metals thus being, in principle, an electrochemical process. Experimental method described can be used to study metals, electrolytes and depolarizing agents in galvanic cells and the reactive behavior of activated carbon.

2.3.9

Emission Microscopy in Metallurgical Research. (In English.) W. G. BURGERS AND G. W. RATHENAU. *Proc. Conf. Electron Microscopy (Delft, July 1949)* 1950, 81-83.

In the emission microscope a suitable specimen (e.g. iron, iron-nickel alloy or zirconium) is coated with a copious emitter of electrons such as cesium. When the specimen is heated strongly, electrons are emitted thermally and can be accelerated and focused in a manner similar to that in the ordinary electron microscope. Since the cesium atoms are differently adsorbed on different crystal faces of the specimen the grains and twins appear as regions of differing luminosity and it is possible to follow, by continuous observation, the movement of grain boundaries and the nucleation and growth of new grains. The limitations of the method are briefly discussed with references to published results.—MA.

APEX

for cathodic protection

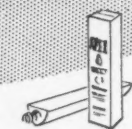
MAGNESIUM ANODES

Corrosion control for under-ground and under-water pipelines and other metal structures regardless of all other methods used.

Anode folders or technical consultation with our engineers available upon request.

APEX SMELTING COMPANY

2537 WEST TAYLOR STREET • CHICAGO 12, ILLINOIS
6700 GRANT AVENUE • CLEVELAND 5, OHIO



APEX Anodes are available in 17 lb. and 32 lb. bare anode with or without wire, or complete packaged anode with wire and back-fill ready for installation.

2.3.9

Applications of the Electron Microscope. (In English.) W. T. ASTBURY. Proc. Conf. Electron Microscopy (Delft, July 1949) 1950, 27-34+.

A survey of recent advances in applications of the electron microscope in biology, with mention of a few results in metallurgy. The similarity of results obtained by electron microscopy, by means of plastic replicas, and phase-contrast optical microscopy is pointed out.—MA.

2.3.9

Use of Radiotracers to Measure Surface Adsorption from Mixtures. C. M. JUDSON and others. *J. Chem. Phys.*, **18**, 1302 (1950) Sept.

Outlines results of some measurements of adsorption of a soluble surface-active agent at the solution-air interface.—BLR.

• Instrumentation

2.4.3

Radioactive Thickness Gauge for Moving Materials. J. R. CARLIN. *Electronics*, **22**, No. 10, 110-113 (1949).

Briefly discusses the methods of continuous thickness measurement and indicates their disadvantages and sources of error. The radio-isotope thickness gauge employs an ionization chamber as the radiation-sensitive device. Either β - or γ -radiation is employed, depending on the material to be measured and on its thickness, β -rays being suitable for thickness measurements from 0.000015 in. of aluminum to 0.1 in. of steel. The absorption of β -radiation by various materials is discussed and complete details

given of the circuits of the complete thickness-measuring instrument. The apparatus lends itself to automatic operation and can be set to control a rolling process.—MA.

2.4.3

New Surface Inspection Technique. G. C. CLOSE. *Mod. Machine Shop*, **23**, No. 3, 80-84 (1950) Aug.; *Product Eng.*, **21**, Nos. 8, 9, 160-161+ (1950) Aug., Sept.

Proprietary process called Dy Chek, developed by Northrop Aircraft Inc. No chemical details given, but processes include thorough preliminary cleaning, application of a chlorinated hydrocarbon (containing a dyestuff) as dye penetrant, followed by a developer. Resultant surface color markings interpreted as evidence of surface defects. Wide application is claimed and all the chemicals are said to be non-corrosive.—BNF.

2.4.3

White Fluid for Magnetic Crack Detection. *Machinery* (London), **77**, 183-184 (1950) Aug. 10.

Describes results of experiments using aluminum powder in paraffin for dark surfaces. Includes photographs.—BLR.

2.4.3

Ultrasonics and Their Use for Non-Destructive Testing of Materials. N. G. NEUWEILER. *Microtecnic*, **4**, No. 1, 37-44 (1950) Jan.-Feb.

The use of ultrasonic waves for the nondestructive testing of materials became possible when the frequency employed was high enough and the wave length short enough to secure rectilinear propagation of the ultrasonic radiation. Since most known materials will transmit ultrasonic waves a few millimeters

or less in length over a useful range of distance, very good prospects of detecting flaws, inclusions, etc., in the interior of opaque bodies are opened. Of the several possibilities of producing ultrasonic waves, the most common and practical is the quartz crystal. A hypothetical explanation of the piezoelectric phenomenon is given; the type of crystals and crystal mounting used is discussed; and two types of circuits for ultrasonic generators are described. The velocity of ultrasonic waves in various media is treated, and propagation velocities of ultrasonic waves in various liquid and solid media are tabulated. Practical application of ultrasonics for testing materials is discussed in detail.—TDD.

2.4.3

Butt Weld Testing with the Hughes Supersonic Flaw Detector. *Machinery* (London), **76**, No. 1959, 667-668 (1950).—MA.

2.4.3

Measurement of Electrical Resistance of Insulating Materials. R. H. NORMAN. Research Assoc. of Br. Rubber Manufacturers; *J. Sci. Instr.*, **27**, No. 7, 200-202 (1950) July.

This paper describes means of overcoming some difficulties which occur when the resistance of insulating materials is being measured by electrometer methods and, in particular, by methods involving guarded electrodes. The methods of measurement considered are capable of measuring resistances up to about $10^{10}\Omega$. Some nonstandard items of the test equipment are described and details about the routine use of a Lindemann electrometer are also given.—TDD.

What's your Corrosion Problem?

James E. Mavor Company has the men and material to help you solve your corrosion problems, whatever they may be. Men who have spent years in corrosion research and in the development of corrosion prevention products are at your service.

Adequate stocks of proven corrosion prevention products are maintained at Houston.

In addition, the strategically located manufacturing plants of our suppliers assure prompt shipment in any quantities.

Our traffic department "follows-thru" on all shipments, from order to delivery, to assure on-time arrival. Our service doesn't stop until the materials are applied.

KOPPERS

BITUMASTIC
REG. U.S. PAT. OFF.

Hot Applied Pipe Line Coatings

Manufactured at: Houston, Texas
Woodward, Ala.; East St. Louis, Ill.;
Chicago, Ill.; Follansbee, West Va.;
Garwood, N. J.

Cold Applied Coatings

Stocked at Houston for immediate shipment

Carey

Asbestos Pipe Line Felt

Direct from factory shipment
Also stocked at Houston for immediate delivery

TAPECOAT

Protective Coatings for Pipe Joints

Stocked at Houston for immediate shipment

Glassfloss

PIPE WRAP

holds larger quantities of enamel on pipe . . . is not subject to deterioration thereby providing longer life for protective coating.

JAMES E. MAVOR COMPANY

514 M & M Bldg., Capitol-2203

T. F. P. KELLY
HOUSTON 2, TEXAS

CHARACTERISTIC CORROSION PHENOMENA

• Electrochemical Effects

3.6, 3.5, 7.2

The Fundamentals of Galvanic Corrosion. A. B. Lauderbaugh. *Gas Age*, 106, No. 5, 20-25+ (1950) Aug. 31.

The principles of galvanic corrosion are described in simple terms and illustrated with striking drawings. Specific conditions are described in which galvanic circuits may be expected to occur to cause corrosion of underground pipe.

3.6, 6.2

Overvoltages in the Oxidation-Reduction System Ferrous Iron-Ferric Iron.

(In French). Eugene Lewartowicz. *Compt. Rend.*, 229, 1326-1328 (1949) Dec. 14.

Results of an experimental study of the above are tabulated and charted.—BLR.

3.6

Electrochemical Thermodynamics and Kinetics of Hydrogen Overvoltage. Pierre Van Rysselberghe. *J. Chem. Phys.*, 17, No. 12, 1226-1231 (1949).

The problem of hydrogen overvoltage is approached by a method of making systematic use of chemical and electrochemical potentials. More precise formulae are thereby obtained than in previous theories, and a more quantitative interpretation of the transfer coeff. of Erdey-Gruz and Volmer (*Z. physikal. Chem.*, 1930, 150, 203) is derived. The Tafel empirical equation is discussed and the exist-

ence, in some cases, of several Tafel regions is considered. Activation free energies, energies and entropies for the discharge process are calculated and the mechanism involving formation of atomic hydrogen is shown to be entirely plausible. The recent discussion of the various theories by Bockris (*Chem. Rev.* 1948, 43, 525) does not require any substantial modification in the light of the present treatment.—MA.

3.6

Some Applications of Electrochemical Thermodynamics. M. Pourbaix. (In French) *Assoc. Ital. Met.*, Second National Congress. pp. 8-24 May, 1948. *Corrosion*, 6, No. 12, 395-414 (1959) Dec. (In English).

Theoretical consideration of electrochemical surface reactions and polarization curves; theoretical and experimental study of the behavior of iron in aqueous solutions; survey of work on electrochemical behavior of platinum.—BNF.

3.6, 6.4, 4.3

Solubility of Aluminum During Cathodic Polarization. (In Russian). B. Kabanov and A. Zak. *Reports of the Academy of Sciences of the USSR*, new ser., 72, 531-534 (1950) May 21.

Solubility of 99.9955 percent aluminum in various alkaline solutions and using current densities of 1-10 amp. per sq. cm was investigated. Shows curves for potassium hydroxide, sodium hydroxide and lithium hydroxide. Results are subjected to theoretical analysis.—BLR.

3.6, 3.8

Primary Principles of [Electrochemical] Corrosion [and Its Relationship to the Adsorptive Properties of a Material.] H. Grubitsch. *Arch. Metallkunde*, 3, No. 11, 394-396 (1949).

Grubitsch discusses: 1. Types and causes of corrosion, 2. The local-element theory of electrochemical corrosion, 3. The topochemistry of corrosion processes, 4. Corrosion as an adsorption process, and 5. The interpretation, in terms of Langmuir's equation, of the relationship between the adsorption and the solubility of pressed compacts produced from copper powder which had been preheated in various ways.—MA.

• Metallurgical Effects

3.7, 6.5, 6.4

Structure and Properties of the Heat-Affected Zones of Welded Aluminum-Copper-Magnesium Stampings. (In German) H. Kostron and A. Muller-Busse. *Metall.*, 4, 41-48 (1950) Feb.

Presents results of a study of structure, hardness, and corrosion resistance of the heat-affected zones of above alloy containing 4.07 percent copper, 1.39 percent magnesium, 0.96 percent manganese, 0.67 percent silicon, and 0.52 percent iron, after gas and arc welding. Data are charted and tabulated. Includes microphotographs.—BLR.

3.7, 6.2, 6.3

Zinc and Iron. A. Kutzelnigg. *Arch. Metallkunde*, 3, No. 12, 439-440 (1949).

Zinc and iron occur together in nature more than any other two metals. The effects of impurities of one metal in the other in relation to their production, properties, applications, and biological effects are briefly reviewed. 21 references.—MA.



Insulating Materials

for PIPE NIPPLES and PIPELINE FLANGES

★ **WRITE FOR VALUABLE, NEW BULLETIN**

For a period of 14 years the Nelson Electric Manufacturing Company has been furnishing Phenolic Insulating Materials for pipe nipples and the insulation of pipeline flanges. We introduced the use of thin-wall tubing sleeves for insulating the studs in standard flanges, without requiring re-drilling of the flange and providing smaller studs. We now offer flange insulation, packaged for immediate shipment on the more common sizes.

Write for 10-page bulletin which describes our Insulating Materials.

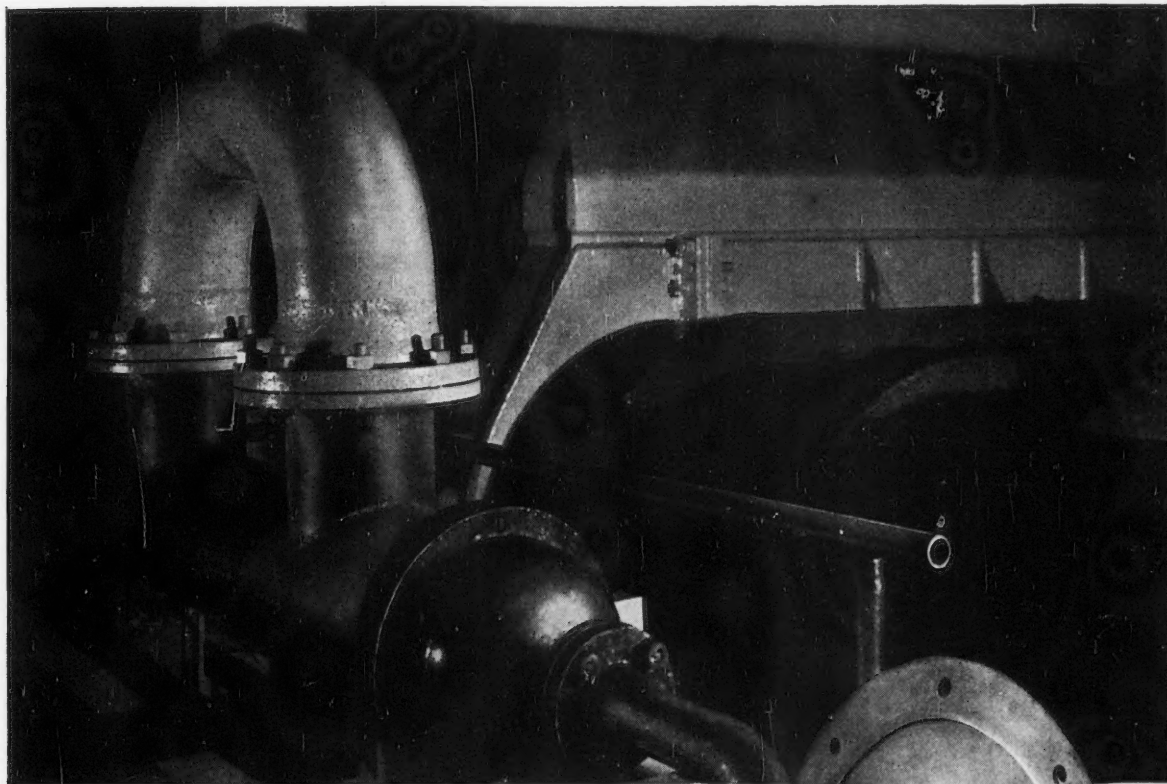
NELSON Electric MANUFACTURING CO.

217 N. Detroit St.

TULSA, OKLAHOMA

Telephone 2-5131

We **like** our tube customers skeptical



Test condenser operating in parallel with main turbine condenser at Narragansett Electric Co. Station in Providence, R. I.

18 tubes are now undergoing performance tests under same cooling water and operating conditions as main unit.

Long ago we learned there's nothing like a good hard fact to convince a prospective customer for heat exchanger or condenser tubes.

The kind of facts our Technical Department likes to give our customers come out of tube performance studies like this 18-tube test condenser installed at the Manchester Street Station of The Narragansett Electric Co. at Providence, R. I. To attempt to reduce tube failure from pitting by polluted harbor water, this test unit was installed at the suggestion and with the help of Anaconda condenser tube specialists. It operates in parallel and under identical conditions with a main turbine condenser. Among tube alloys under test are Arsenical Admiralty 439, Ambraloy 927 (Aluminum Brass), Ambraloy 901 (Aluminum Bronze), Super-Nickel 702 and Cupro-Nickel 754.

We are sure that our Technical Department's extensive facts and long experience with the performance of ANACONDA Tubes under almost every type of operating condition can help you select the right heat exchanger or condenser tube. May we make them available to you? The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

51126

for efficient heat transfer **ANACONDA**[®] HEAT EXCHANGER TUBES

253a

3.7, 5.4, 2.3

Tests Made With Spot-Welding Lacquers. Cornelius. PB. 98651, 10 pp. NPVL Abs. 1950 No. 154, 38.

Four spot-welding lacquers were applied to steel strips and tested to determine the effect of storage time on the effectiveness of the spot-weld. Tests also consisted of determining the effect of corrosion on the protective effect of the coating at spot-welded joints after an alternate dipping into tap water and into a solution of table salt.—RPI.

CORROSIVE ENVIRONMENTS

• Water and Steam

4.6, 8.4

Recirculating Cooling System Waters. E. G. Hammerschmidt. *Petro. Eng.* D-77 + (1950) Mar.

It is the purpose of this article to review the history of water conditioning of station cooling waters as pertains to Texoma Natural Gas Co. operations and to state the best opinion, at the present time, of what it takes to operate the water cooling systems properly.—GPC.

4.6, 5.7, 5.8

Water Treatment for Cooling Towers. J. B. Davis, Allis-Chalmers Mfg. Co. *Heating, Piping Air Cond.*, 22, No. 4, 89-93 (1950) Apr.

A general discussion of the subject of water treatment for cooling towers includes types of cooling systems, cooling system problems, characteristics of deposits, troublesome calcium carbonate, control of corrosion, scale prevention procedures, control procedures and operating range and selection of water treatment. Selecting corrosion resistant construction materials is the approach to controlling corrosion. Protection by chemical treatment requires care in selection of chemicals and a rigid control procedure. Corrosion may be minimized by depositing a film of calcium carbonate on the metal surface in controlled amounts, removing corrosive gases from the water, or using chemical inhibitors or a combination of all three. Scale preventive procedures fall into the classes of softening, alkalinity reduction, surface active treatment, deconcentration and sterilization. Tables and graphs of data are given.—INCO.

PREVENTIVE MEASURES

• Cathodic Protection

5.2

The Use of Wind-Driven Generators as an External Source of Protective Currents for Cathodic Protection. M. L. Jacobs. Symposium on Cathodic Protection, Electrochem. Soc. and NACE, 77-79 (1949).

The combined use of wind-driven generators and magnesium anodes is proving itself to be a very economical and effective method of pipe-line protection. Fewer anodes are required than when the whole protection is carried out with anodes, and the deterioration of the

anodes per year is also less. Typical cost figures are given for the protection of 25 miles of poor to fairly well coated 8-in. pipeline over a period of 15 years. The cost of protection with magnesium anodes is \$11,024, with combined magnesium anodes and wind plant \$2752 and with a rectifier \$4252.—MA.

5.2, 8.4

Cathodic Protection Goes Offshore. E. P. Doremus and G. L. Doremus. *Oil Gas J.*, 49, No. 7, 222 + (1950) June 22.

High density polarization of under water equipment to form a calcareous coating cuts down subsequent current requirements. The application of magnesium anodes, their approximate cost and typical uses are included.

5.2

Requirements of Cathodic Protection System. F. E. Dolson. *J. Am. Water Wks. Assoc.*, 41, 413-416 (1949); *Water Pollution Abstr.*, 22, 271 (1949) Dec.

The principle of cathodic protection of steel is described and a method outlined for the determination of current density required to prevent corrosion of a tank.

5.2, 3.5

Behavior of Experimental Zinc-Iron Couples Underground. I. A. Denison and W. Romanoff. Symposium on Cathodic Protection, Electrochem. Soc. and NACE, 144-152 + (1949).

The protection of iron by means of zinc anodes was investigated in 8 different soils. The cathode of the couple was an iron ring having an area of 42 sq in, and to this were connected from 1 to 3 zinc anodes to provide different area ratios of zinc to steel. In 6 of the 8 environments corrosion of the steel was prevented over the period of the tests, which lasted from 3 to 6 years, although a greater area of zinc was required in some soils than in others. Measurements of electrode potentials are interpreted in terms of the extent to which cathodic protection was provided. The increase in potential which resulted when one or more zinc anodes were connected to the iron rings was found to indicate prevention of corrosion only in the case of those cathodes whose potentials were already strongly anodic to the reference electrode. Those cathodes whose open-circuit potential was less anodic were not protected by being connected to zinc anodes. Minimum protective currents as obtained from current/potential curves were of the same order of magnitude as the average current of the couples calculated from DC measurements, from loss in weight of the zinc anodes, and from loss in weight of the unconnected steel rings. This agreement is interpreted as indicating that in the environments studied no more current is required for protection than is equivalent to the loss in weight produced by normal corrosion. 13 references are appended.—MA.

5.2, 1.2

Economic Factors Bearing on Application of Cathodic Protection. D. B. Good. Symposium on Cathodic Protection, Electrochem. Soc. and NACE, 80-87 (1949).

The need for a sound engineering and economic approach to the problems of cathodic protection, whether by means of rectifiers or sacrificial anodes, is stressed. The factors involved in deter-

mining the economics of cathodic protection are listed and briefly discussed.—MA.

5.2, 5.4

Relations Between Protective Coatings and Cathodic Protection. Guy Corfield. Symposium on Cathodic Protection, Electrochem. Soc. and NACE, 189-191 (1949).

It is shown that the resistance of the protective coating is one of the most important factors in the design and operation of a cathodic protection system. To obtain dependable design data it is necessary to make preliminary field tests by actual application of current to the structure to be protected.—MA.

5.2

The Performance of Magnesium Galvanic Anodes in Underground Service. O. Osborn and H. A. Robinson, Dow Chem. Co., Paper, NACE 6th Ann. Conf., St. Louis (1950) April 4. Abstr. *Ind. & Power*, 58, No. 5, 155 (1950) May.

The performance of magnesium galvanic anodes in underground service is reviewed in the light of the past five years of field testing in which some 2500 anodes were tested in 40 different backfills and in various soils.

5.2

Locations and Materials for Anodes for Impressed Current [for Cathodic Protection]. Derk Holsteyn. Symposium on Cathodic Protection, Electrochem. Soc. and NACE, 88-92 (1949).

Steel, graphite or carbon anodes are normally used, but the use of galvanized steel is briefly mentioned. A further possibility is the use of metals surrounded by a chemical solution in a porous pot, e.g. lead in sulfuric acid. 8 references are appended.—MA.

5.2, 6.4, 4.6

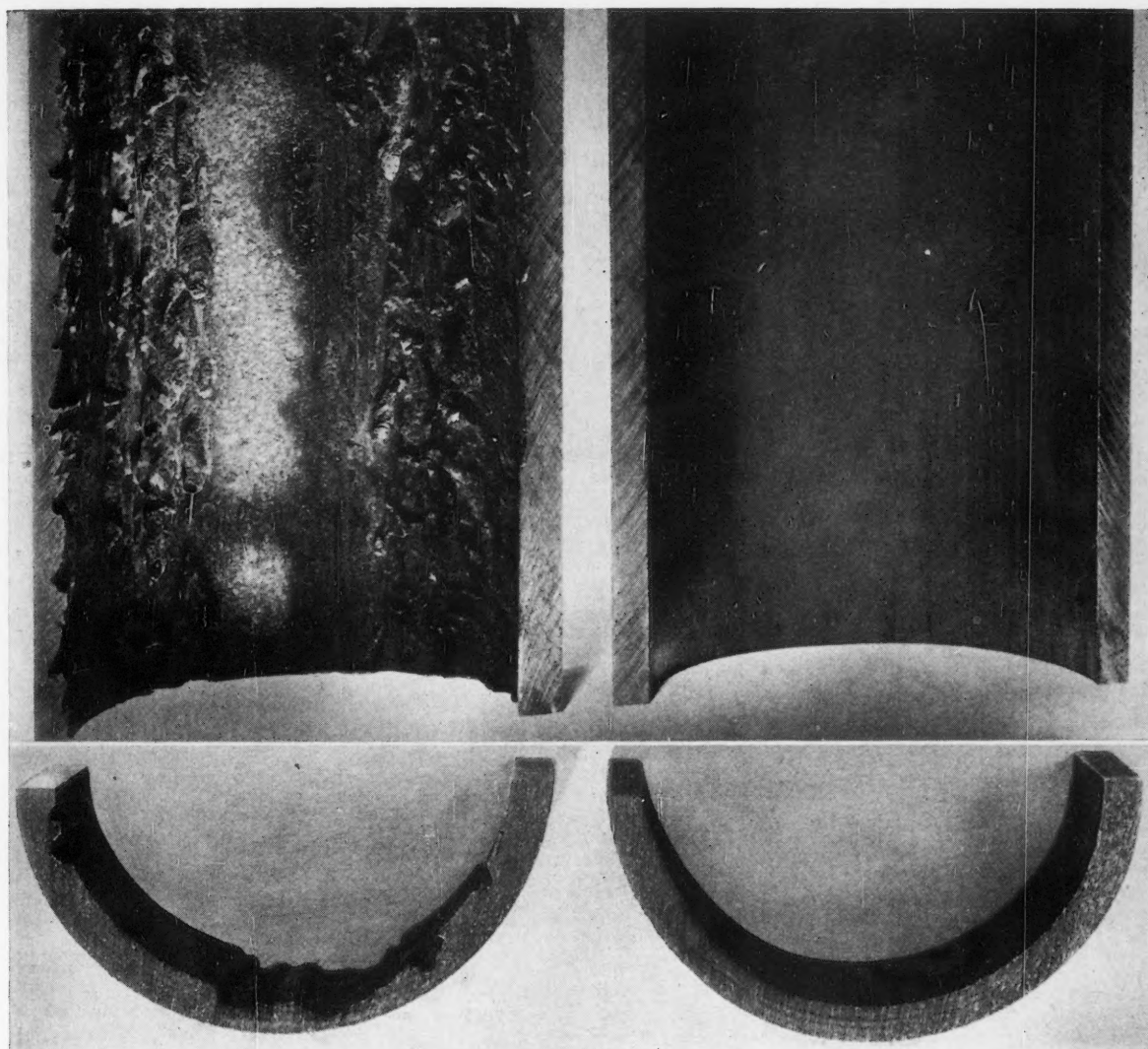
Cathodic Protection—I.—II. *Light Metals*, 12, No. 132, 43-50; No. 133, 84-93 (1949).

I. A discussion of the performance of aluminum alloy anodes. Aluminum-zinc alloys are suggested as the most promising materials for the protection of steel structures. The operating characteristics of magnesium alloy anodes in sea-water described. The problem of backfills for aluminum and magnesium anodes is also discussed. II. Installation details and the results obtained are described. The protection of certain stainless steels, steel in sea-water, and lead cable sheathing are instanced. 17 references are given.—MA.

5.2, 7.2

The Installation and Economics of Placing Magnesium Anodes at Leaks Repaired on a Pipe Line. J. A. Holloway, Houston Pipe Line Co. Paper before NACE, South Central Reg. Mtg., Dallas, Oct. 3-4 (1949). *Corrosion*, 6, No. 5, 157-161 (1950) May.

Magnesium anodes can easily be installed when leaks are repaired and they help the anodic areas of the pipe furnish current for the controlling cathodic areas. Leak frequency charts indicate that a reduced rate of corrosion is attained until complete cathodic protection can be installed.—INCO.



Don't Let Corrosion Steal Your Steel!

A major oil company coated the inside of 4-inch steel tubing with finishes based on VINYLITE Brand Resins. Each day, for five months, the pipe carried 100 barrels of oil and 5,000 barrels of high-iodine-content salt water. It was directly coupled to an uncoated pipe.

The coated pipe (right) suffered no measurable damage. The uncoated pipe (left) corroded as deeply as a quarter of an inch — two-thirds of the way through the pipe.

Preserving metal and slashing

maintenance costs, coatings based on VINYLITE Resins are widely used today in the petroleum, chemical, and processing industries...because they resist water, salt air, industrial atmospheres, oils, greases, alkalies, most strong acids, sunlight, heat, cold. Odorless, tasteless, non-flammable, they protect containers from contents, contents from containers.

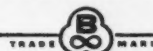
We'll gladly send you a list of suppliers of metal, concrete and masonry coatings based on VINYLITE Resins. Write Dept. KX-69.

Coatings illustrated applied by Liquid Plastics Co., 640 N. Broad Ave., Wilmington, California and produced by Plastic Coating Corp., Houston 19, Texas, and 30 Rockefeller Plaza, New York 20, N. Y.

Vinylite

BRAND

RESINS



BAKELITE COMPANY

A Division of
Union Carbide and Carbon Corporation
30 East 42nd Street, New York 17, N.Y.

• Non-Metallic Coatings and Paints

5.4, 4.3

Yellowing of Greens by Handling. N. R. Risk. *Paint Tech.*, 14, No. 167, 486 (1949).

It is suggested that the yellowing which occurs when articles coated with chrome green paint are handled may be due not merely to wearing away of the blue surface layer (which results from the floating of the Prussian blue) but also to the destructive action of perspiration on this pigment.—RPI.

5.4, 7.1

Permanent Resin Coating for Steel Engine Parts; Investigation of Incorporation of Nylon. D. L. Dorfman. PB. 98665, 13 pp.; NPVL Abs., No. 154, 34 (1950).

Tests were made to determine whether the toughness and adhesion of, and the protection afforded by, permanent resin coatings for steel engine parts were improved by the addition of nylon. The unmodified sample performed satisfactorily in all tests. The samples modified with various percentages of nylon were equal, but not superior to, the original resin in the film durability and salt spray tests and were somewhat inferior in the flexibility test.—RPI.

5.4

Story of the Paint and Varnish Industry of Japan. S. Oshima. *Paint Oil Chem. Rev.*, 113, No. 11, 42-43.

A short account of the history of paint manufacture in Japan, the search for substitutes in the war years, including research on hot-applied plastic paint for ships, benzyl cellulose lacquers, current practice and trade statistics.—RPI.

5.4

Corrosion Resistant. *Tool Eng.*, 24, No. 5, 76 (1950) May.

The sealing power of a corrosion and oxidation resistant coating, End-o-Rust, is adapted with success for use on concrete, wood, or any surface where more than normal protection is needed, as well as for use on metals. No special preparation of the surface is needed and complete protection is achieved without costly dip and heat treatment. It dries in air in 2-3 hrs. Mfd. by End-O-Rust, Inc. —INCO.

5.4

Lacquers for Metals—General and Special Applications. E. S. Tonks. *Met. Ind.*, 76, No. 11, 209-211 (1950) Mar. —MI.

5.4, 6.4, 2.3

Vinyl Finishes for Aluminum Alloys. W. A. Edwards. *Light Metals*, England, 13, No. 14, 336-339 (1950) June.

Vinyl stoving lacquers are usually based on co-polymers of vinyl acetate and vinyl chloride, with other ethenoid materials being sometimes introduced into the polymer molecules. The resins are dissolved in suitable solvents, and pigments may be added to produce a wide range of pastel shades. Properties of the lacquer films are as follows: 1. stoving for only very short periods, 3-5 minutes at 260 degrees F (127 degrees C) is usually adequate; 2. tenacious adherence to all aluminum alloys and sufficient elasticity to withstand bending through 180 degrees; 3. excellent resistance to immersion for one month in petrol or benzol, to soap and dilute alkali solutions, oils or fats, or acid solutions such as concentrated fruit juices; 4. water proof; 5. poor resistance to heat—continued exposure to temperatures above 210 degrees F (99 degrees C) leads to discoloration and eventually to reduced adhesion. A different spraying technique is necessary for vinyl lacquers from the usual synthetic enamels, particularly for vertical surfaces. Roller-coating methods as well as spraying are possible with horizontal surfaces. Tests were conducted of the coating on various aluminum alloys by exposing the specimens to accelerated corrosion tests, such as salt spray or in a humidity cabinet in which the temperature varies continually between upper and lower limits. Typical specimens are illustrated which were exposed to salt spray for 3½ months; they were coated by dipping with a clear vinyl lacquer and stoved at 260 degrees F for three minutes, to give a film weight of 1¼ oz. per sq. yd. An aluminum bowl coated internally with one coat of white vinyl lacquer and used continuously in the kitchen for 16 months, in contact many times each day with hot water and hot soap solutions, is illustrated. The condition is still satisfactory apart from a certain amount of mechanical damage. Other possible uses are for coating washing machine parts, kitchen cabinets and food-storage bins. The finishes are non-poisonous and devoid of odor.—ALL.

ROSKOTE cold-applied anti-corrosion mastic saves time...saves money...SAVES PIPE!

Roskote's drying speed, its handling ease and its high electrical resistivity makes it the ideal mastic for pipeline protection, winter or summer. Whether you are protecting distribution and service lines, or large transmission lines in yard or field, it will pay you to investigate...



ROSKOTE



cuts field costs because it is applied COLD—either brush, spray or special line-traveling machine—without primer or field mixing. It eliminates labor, equipment and hazards of hot-applied materials. It is fast-setting to a tough, flexible film of high electrical resistivity (20 megohms per sq. ft.) without brittleness or sag through a temperature range of -40° to 375°F. It dries to the touch in 20 minutes and is ready for backfill in an hour.

Roskote's resin base resists acids, alkalis, salts and moisture. It bonds readily to previous coatings of coal tar or asphalt. Wire brushing is the only preparation needed for old pipe.

Roskote's drying speed and handling ease cuts man-hours from work schedules and speeds pipe-line progress. That

saves real money! Yet Roskote costs only 3¢ per square foot of coverage.

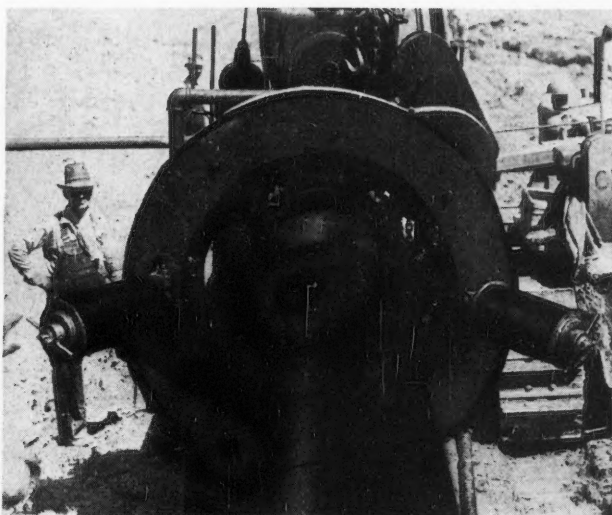
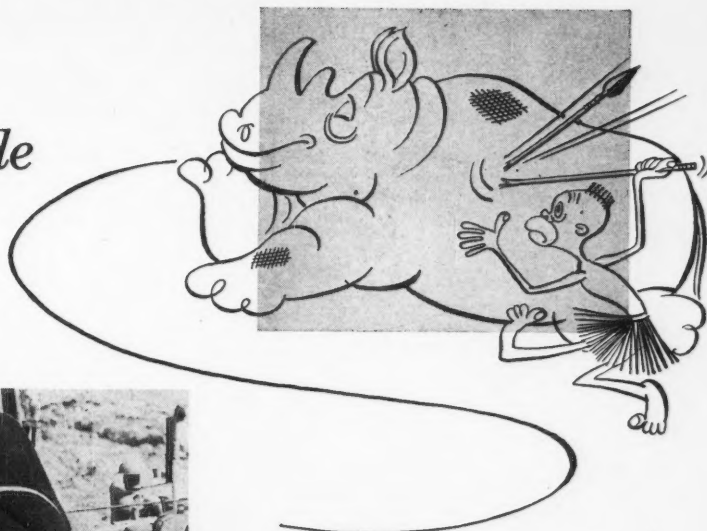
Used by over 70 utilities and pipeline companies for coating at "hot spots," road crossings, for valves, joints, meters, drips; for patching and for waterproofing concrete regulator pits.

Write for bulletin containing complete technical specifications, chemical and electrical properties and application information. Ask for the Roskote special trial order offer.

ROYSTON
LABORATORIES, INC.,
BLAWNOX, PA.

MANUFACTURERS OF QUALITY INDUSTRIAL COATINGS RESISTANT TO CORROSION BY ACIDS, ALKALIES, ELECTROLYSIS, HEAT, MOISTURE AND WEATHER.

*Like the
Rhino's tough hide
that protects
what's inside...*



MORE than 100,000 miles of oil and gas pipe lines are now protected by Johns-Manville Asbestos Pipeline Felt—the only type of wrapper that has survived over 50 years of service in all types of soils.

Johns-Manville Asbestos Felt is a sturdy, inorganic product. It has the thickness and toughness necessary for shielding pipeline enamels from earth load and soil stresses. It is resistant to rot and decay, and to acid and alkali soils. It permits the protective enamel coating to properly function against corrosion.

Johns-Manville
Asbestos
PIPELINE FELT

Johns-Manville

**Asbestos Felt protects
oil and gas pipe lines**

Johns-Manville Asbestos Felt is flexible. It wraps easily without cracking. It guards enamel from impact during installation of field-wrapped pipe, or during transportation and installation of mill-wrapped pipe.

There are economic advantages, too. In addition to reducing maintenance expense, Johns-Manville Asbestos Felt adds many years of life to the pipeline. For further information and a sample of Johns-Manville Asbestos Pipeline Felt, mail the coupon below.



Johns-Manville
Box 290, New York 16, N. Y.

Please send me a copy of the sample folder on
Johns-Manville Asbestos Pipeline Felt, PP-22A.

Name _____

Address _____

City _____ Zone _____ State _____

CUT CORROSION PROBLEMS DOWN TO SIZE...

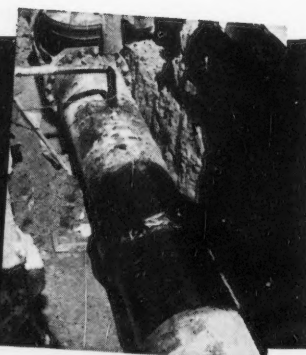
WITH TAPECOAT*

—the Coal Tar Coating in Handy Tape Form

—Sized to the job

24" WIDTH

TAPECOAT — the economical coal tar coating for "cigarette-wrapping" mechanical couplings, large diameter pipe, joints, bends and drips.



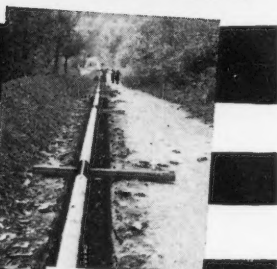
18" WIDTH

TAPECOAT—the practical coal tar protection for "cigarette-wrapping" of large couplings, pipe bends, and joints on large diameter pipe.



6, 4, 3, and 2" WIDTHS

TAPECOAT — the distinctive, time-tested coal tar tape for spiral-wrapping welded field joints, service connections, pipe under streets and sidewalks, and pipe through building walls.



For more than 10 years, Tapecoat engineers have specialized in pipe joint protection. Call on them to help you meet your individual requirements. Write today for complete details.

The TAPECOAT Company

Originators of the Coal Tar Tape for Pipe Joint Protection

1521 Lyons St., Evanston, Illinois

*Reg. U.S. Pat. Off.

5.4, 6.5, 2.1, 3.4

Corrosion of Metals Underground. I. A. Denison and M. Romanoff, Nat. Bur. Standards. *Nat. Bur. Standards Tech. News. Bull.*, 34, No. 4, 48-49 (1950) Apr.

Approximately 3000 specimens of representative pipe materials, exposed to soil corrosion for periods up to 14 years, have been examined, and the weight loss and depth of pitting have been measured and interpreted. The specimens were buried at 15 test sites widely separated throughout the U. S. Corrosion of cast iron, steel and wrought iron is a natural consequence of the normal physical, chemical and biochemical action of soils on metal surfaces. Copper and its alloys with silicon, zinc, and nickel are highly corrosion resistant in soils that are very corrosive to ordinary iron and steel. The copper alloys, however, differ widely in corrosion resistance depending on environmental conditions, i.e. in soils high in sulfides, copper corroded at an appreciable rate, but low-copper brasses were resistant. Certain steels containing high percentages of chromium and nickel were resistant to corrosion in a more absolute sense. Measurements of corrosion of wrought iron specimens show that small amounts of chromium, nickel and molybdenum, which produce high resistance to atmospheric corrosion in modern high-strength steels, contribute little to their corrosion resistance underground, because conditions in the soils do not favor the formation of tight, adherent rust deposits, on which the corrosion resistance of these steels in the atmosphere depends. The one environmental condition that has the dominant influence on pitting and weight loss with time is aeration.—INCO.

5.4

Building Organic Protective Coatings to Special Requirements. K. G. Compton. *Corrosion*, 5, No. 5, 148-150 (1949).

A brief outline is given of the formulation of paint-type coatings. The use of aluminum and zinc powder as pigments is mentioned. Information is also included on the formulation of an enamel suitable for coating zinc-base die-castings.—MA.

5.4

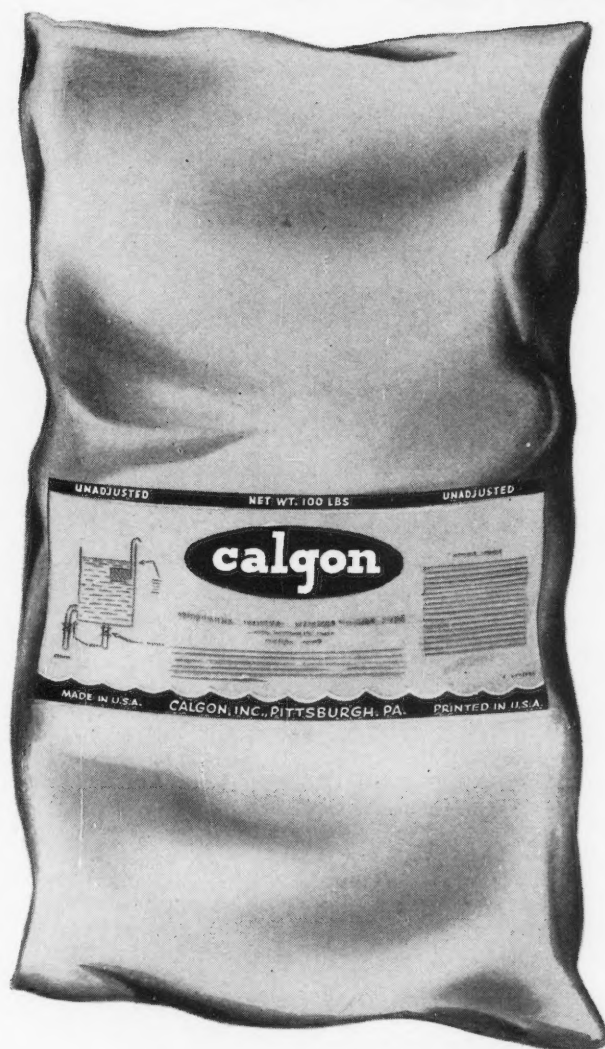
Vinyls for Metal Decoration. R. A. Calsibet. *Am. Ink Maker*, 27, No. 7, 33-34, + (1949).

Vinyl resins (described) have become established in the field of specialty coatings by virtue of their outstanding properties and performance under severe conditions. The use of dispersions, organosols, plastisols and hydrosols should considerably reduce expenditure because of the very low solvent costs and the high solids obtainable. The very tough flexible films produced may eventually find a place in coatings for signs and toys. With further improvements in handling technique, wash primers pigmented with chromates may replace elaborate metal pretreatment systems. Zinc-chrome pigment cannot be used for food containers, but the unpigmented finish may be useful as a bond coat, possibly applied at the sheet mills. Its excellent adhesion to many metals and the ability of other metals to adhere to it are important.—RPI.

5.4, 2.2

The Performance of Certain Stoving Paints on Other Painting Schemes Used to Protect Steel Sheet Against Atmos-

Proved Performance



IN THOUSANDS OF COOLING WATER SYSTEMS

Calgon* has proved its ability to maintain clean, efficient heat transfer surfaces in literally thousands of recirculating and once-through cooling water systems. Moreover Calgon minimizes maintenance and eliminates costly unscheduled shut-downs.

How can Calgon give such a stellar performance? Because Threshold Treatment with Calgon not only controls corrosion but prevents the deposition of scale as well!

Our engineers will be glad to discuss your specific cooling water problems with you. For more detailed information send for free Threshold Treatment bulletins.

*T.M. Reg. U.S. Pat. Off.

HAGAN
HALL
BUROMIN
CALGON

calgon, inc.

A SUBSIDIARY OF
HAGAN CORPORATION

HAGAN BUILDING
PITTSBURGH 30, PA.

phoric Corrosion. J. C. Hudson. *Paint Technol.*, 15, No. 171, 101-104 (1950) Mar.

Eight two-coat systems of both stoving and air-drying paints were exposed for five years at Selly Oak, Birmingham, in an urban and moderately corrosive atmosphere. Five paints, including a 100 percent phenolic resin stoving paint system, in which the primer was pigmented with zinc oxide and barytes and the finishing coat with red iron oxide, did not show more than 0.05 percent rusting after five years and was the outstanding protective scheme of the series. A zinc chromate and Burntisland red formulation in 100 percent phenolic resin medium endured for 4.2 years and the same pigmentation in a modified phenolformaldehyde/stand oil medium failed after 3.6 years.—ZDA.

5.4, 4.6, 5.9, 1.7

Performance of Anti-Corrosive Compositions in Sea Water. F. C. Hudson. *J. Iron Steel Inst.*, 165, 314-334 (1950) July.

The paper presents and discusses the results of the Marine Corrosion Subcommittee's researches which show that different methods of surface preparation have a marked effect on the performance of anti-corrosive compositions in sea water. Paint gives poor protection against exposure to sea water if applied over mill scale. Since, however, some paints fail to adhere to a completely descaled, freshly prepared and unruined steel surface, it is recommended that the descaled steel surface be allowed to rust slightly or be treated with phosphoric acid wash before the application of the priming coat of anti-corrosive composition. In the case of ships' hulls, weathering the steel plates until they have shed their mill scale completely should therefore yield good results. In practice it is difficult to ensure complete descaling of all the component parts of a ship's bottom, and descaling of the plates by grit-blasting or by pickling, followed by a short weathering period or treatment with a surface wash is recommended. Rates of pitting up to 0.16 in. per year have been observed at "holidays" (bare areas in a paint film) on an immersed steel plate. The presence of intact mill scale beneath the paint may also promote pitting, but if about 90 percent of this is removed by weathering, pitting will probably be no more severe than when the mill scale is removed by pickling. The procedure of launching a ship with the bottom unpainted is not recommended because, owing to the slower removal of mill scale, pitting may result; it is also difficult to clean the surface before painting. With a few exceptions, the relative behavior of a given set of bottom painting schemes is the same whether applied to new specimens of unpainted steel or to specimens which have previously been painted and exposed to an immersion test. This applies in the main to both the protective and anti-fouling properties of the painting schemes. Formulated anti-corrosion compositions developed by the Marine Corrosion Subcommittee give good results as priming paints under a bottom painting scheme. A mixed red lead and white lead paint in linseed oil is less satisfactory, although much better than a red iron-oxide paint in linseed oil. Zinc or aluminum coatings on steel improve the performance of bottom painting schemes applied over them; lead, however, pro-

motes pitting. Results of a raft test and those of a patch-painting trial are in good agreement.—TIME.

5.4

Lacquers for Metals: Development of Protective Organic Films. E. S. Tonks. *Metal Ind.*, 75, No. 11, 207-208 (1949); *Bull. Brit. Non-Ferrous Metals Research Assoc.*, 29, No. 245, 469 (1949).

An account of the development of lacquering processes, considering shellac, hot lacquering, use of NC in amyl and butyl acetate; properties of NC lacquers; synthetic lacquers and urea/formaldehyde resin.—RPI.

• Packaging

5.6

Protecting Fixtures and Patterns in Open Storage. H. N. Smith. *Iron Age*, 163, No. 26, 55-57 (1949) June 30.—MI.

• Treatment of Medium

5.7, 7.6, 8.4

Tower Corrosion Arrested with Boiler Blow-Down Water. *Oil Gas J.*, 49, No. 17, 84 (1950) Aug. 31.

Successful use by the Ohio Oil Co. in California of boiler blow-down water to neutralize the low pH (4.5) of the distillate in the top of a vapor stripper is described.

• Surface Treatment

5.9, 3.8

The Theory of Phosphatizing (and the Successful Phosphatizing of Aluminum). A. Wüstefeld. *Arch. Metallkunde*, 3, No. 7, 253-255 (1949).

The characteristic features of phosphatizing in acid and in alkaline solutions are described, and, in both cases, are shown to be based on the same fundamental principles. Colloids form in the complex solutions by removal of the excess hydrogen or hydroxyl ions, such colloids having an opposite charge to that of the metal being attacked. They then discharge at the metal surface, and form a thin, well-bonded layer, which gradually builds up. It is difficult to phosphatize aluminum in acid baths as, owing to the solution of the aluminum, flocculation, and the rapid decrease in pH, aluminum phosphate colloids tend to lose their positive charge before they reach the metal surface. Successful treatment of aluminum can be carried out, however, if the following process is used: 1. Degrease and pickle in a 5 percent sodium hydroxide solution at 50 degrees C for 5 minutes. 2. Wash with cold water. 3. Treat for 15 minutes in a solution containing hydrated aluminum sulfate 111.0 g/l, zinc phosphate 1.98 g/l, 84 percent phosphoric acid 11.7 ml/l, 20 percent sodium hydroxide 306 ml/l, anhydrous sodium carbonate 7.3 g/l, powdered cupric oxide 0.25 g/l, and 2 percent mepasinsulphaminoacetic acid 5.0 ml/l; pH 11.40. 4. Wash with cold water and dry. The zinc and sodium salts in the phosphating solution act as accelerators, the cupric oxide as a depolarizer.—MA.

MATERIALS OF CONSTRUCTION

• Non-Ferrous Metals and Alloys—Light

6.4

ZK60: An Improved Magnesium Extrusion Alloy: History, Characteristics, Service Experience, and Future Prospects. Evan H. Schuette, Dow Chemical Co., Midland, Mich. Presented at the S.A.E., National Aeronautic Meeting, Los Angeles, Oct. 5-8, 1949.

Strength, toughness, and notch-insensitivity are combined with light weight in ZK60, a magnesium alloy containing about 5.7 percent zinc and 0.6 percent zirconium. This combination of properties can be largely attributed to the grain-refining effect of zirconium on magnesium. Its comparative notch-insensitivity is evidenced by its high tensile strength in riveted joints or other assemblies involving holes. Fatigue properties are equivalent to those of the best commercial magnesium alloys. These factors make either type suitable where shock and impact resistance as well as good fatigue properties are required.

The high-strength properties of ZK60, which make it satisfactory for primary structural use, are due largely to small grain size. These properties, however, particularly the compressive yield strength, are also dependent on extrusion conditions such as temperature, speed of extrusion and reduction during extrusion. Typical values for tensile strength, tensile yield, and compressive yield are about 50,000, 33,000 and about 30,000 psi respectively. Elongation is about 11 percent for ZK60 (extruded) and 9 percent for ZK60A (extruded and aged). The modulus of elasticity, 6,500,000 psi, is the same as for other magnesium alloys.

ZK60 is not recommended for service at elevated temperatures. The properties recorded are assumed to hold up to 180 degrees F. Its atmospheric and salt-water corrosion rates are about the same as those of the commercial cast alloys, therefore the bare alloy is not recommended for service in excessively humid or salt bearing atmospheres, although painted ZK60 has been satisfactory for as long as 3 years. Stress-corrosion failure may occur when continuously applied stresses exceed 18,000 psi.—PDA.

6.4, 3.6, 2.3, 3.2

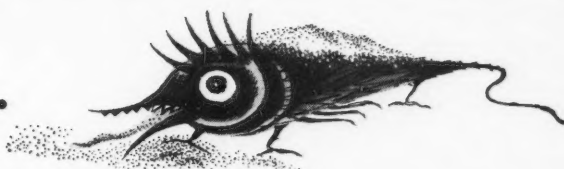
Study for Development of New Stabilized High Strength Aluminum Alloys, Final Report. E. H. Kineski. Cornell Aeronautical Laboratory Report No. KA-496-M-4, 64 pages (1949) June. (TN775 Un3s.)

Considers the intergranular corrosion stabilization of 24S-type aluminum alloy. Reviews literature research and describes development of a micro solution-potential measuring technique, and experimental investigation of effect of various elements on electro-solution potential. Includes tables, graphs, photographs, and micrographs. 40 ref.—BLR.

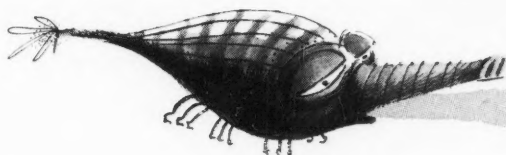
Corrosive fumes...



Salt air...



Hot air...



Moist air...



SO WHAT!

"KARBATE"
BRAND

*impervious graphite pipe
takes it all in stride!*

Have you thought about corrosion *on the outside* of your plant piping? Fumes, salt air, hot air, moist air, can eat up *the exterior* of piping, fittings, valves, pumps, and other equipment around a chemical plant. And it costs money to protect ordinary metal surfaces. You have to sandblast, use special coatings, and even then you find the corrosion creeping in and chewing up the equipment...

NOT SO WITH "KARBATE"

IMPERVIOUS GRAPHITE!

Here are the advantages:

- No exterior protection needed
- Both acid-resistant and alkali-resistant
- Light in weight, easy to machine and assemble
- No metallic contamination of product
- Immune to thermal shock
- Very high thermal conductivity

*The term "Karbate" is a registered trade-mark of
Union Carbide and Carbon Corporation*

NATIONAL CARBON COMPANY
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street, New York 17, N. Y.

District Sales Offices: Atlanta, Chicago, Dallas,
Kansas City, New York, Pittsburgh, San Francisco

IN CANADA: National Carbon Limited
Montreal, Toronto, Winnipeg

Other **NATIONAL CARBON** Products

HEAT EXCHANGERS • PUMPS • VALVES • PIPING • TOWERS • TOWER PACKING • BUBBLE CAPS •
BRICK • STRUCTURAL CARBON • SULPHURIC ACID CUTTERS • HYDROCHLORIC ACID ABSORBERS

FOR BETTER PROTECTION

IN 1952...

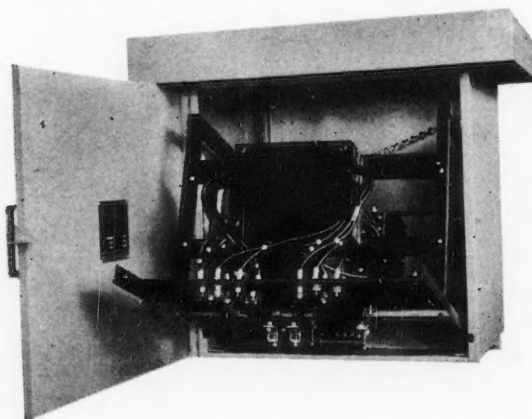
INSTALL THE RECTIFIERS
WITH ALL THE DESIRED FEATURES



SELENIUM RECTIFIERS

Available in either Oil Immersed or Air Cooled types in a complete range of sizes and capacities to meet your most exacting requirements.

C.S.C. Rectifiers feature the latest designs for easy accessibility, quick installation and dependable performance.



We cordially invite you to visit our new Factory and General Offices

CATHODIC SERVICING COMPANY

PHONE 4-2489 134 HEAVY TRAFFICWAY TULSA, OKLAHOMA

• Metals Multiple or Combined

6.5

Uses of Perforated Metals in Industry. F. P. Hutchinson, Harrington & King Perforating Co. *Ind. Sheet Metal*, 2, No. 10, 5-8 (1950) July.

A brief history of the perforating industry is given. Perforations are available in steel, stainless steel, Monel, aluminum, bronze, plastics, etc. The range of holes available, thickness of metal and holing accuracy to avoid corrosion and abrasion are discussed. Applications are listed.—INCO.

6.5, 5.9

Surface Treatments for Aluminum and Its Alloys. R. Gadeau. *Usine Nouvelle*, 6, No. 18, 37-38 (1950).

A review.—MA.

6.5, 3.5, 3.7

Aluminum-Zinc-Magnesium Alloys: Their Development [Stress-Corrosion], and Commercial Production. E. H. Dix, Jr. *Trans. Am. Soc. Metals*, 42, 1057-1127 (1950).

Dix reviews the metallurgical aspects of the development of aluminum alloys of the 75S type (zinc 5.6, magnesium 2.5, copper 1.6, manganese 0.3, chromium 0.25 percent). Since the biggest obstacle to the development of these alloys was their poor resistance to stress-corrosion, the paper is largely concerned with this subject. However, several other aspects of the alloy are discussed in detail, including its heat-treatment, constitution and metallography. The effects of minor alloying additions are considered. Some hitherto unpublished work on the effect of chromium on the stress-corrosion-resistance of the alloy is described. In the absence of chromium the precipitate in heat-treated 75S is highly anodic to the matrix, and many of the larger particles lie in the grain boundaries, thus explaining the susceptibility of the alloy to stress-corrosion. The presence of chromium apparently results in the formation of a submicroscopic precipitate, the grain boundaries being cathodic to the grains themselves. 48 references.—MA.

• Non-Metallic Materials

6.6

Durable Industrial Parts Molded from Thermosetting Plastic-Rubber Blend. *Mat. & Meth.*, 31, No. 6, 67-68 (1950) June.—MI.

6.6

The Thermoplastics. W. Schack. *Mat. & Meth.*, 31, No. 3, 70-80+ (1950) Mar.—MI.

6.6

Plastics vs. Metals in Engineering Applications. W. Schack. *Mat. & Meth.*, 31, No. 3, 49-52 (1950) Mar.—MI.

6.6, 2.2

Effect of Outdoor Exposure on Plastics. J. K. Long. *Modern Plastics*, 27, No. 3, 107-10+ (1949).

6.6, 2.3

Report on Testing and Evaluation of Organic Plastics. G. M. Kline. U. S. Quartermaster Corps, Q. M. Project No.

**Quit cussing about
pipe repairs and
replacements
—and DO
SOMETHING!**

**install
corrosion
resistant**

**SARAN
LINED**

**steel
pipe**

Right now is the time to act! Cut pipe repairs and replacements! Specify corrosion-resistant saran lined steel pipe! You'll find, as have many of the country's leading manufacturers, that this remarkable pipe means dependable long term operation at a minimum maintenance cost. Saran's unusual resistance to most chemicals and solvents plays an important part in the reduction of shutdowns due to pipe repairs and replacements. Another noteworthy advantage is its ease of field fabrication involving NO costly delays with special tools or handling.

These advantages are all important to you, so "quit cussing and do something." For detailed information mail this coupon to the Saran Lined Pipe Co. Saran lined steel pipe is manufactured by The Dow Chemical Company.

Distributed by

Saran Lined Pipe Company

2415 BURDETTE AVE. • FERNDALE, MICHIGAN
With Offices in New York • Boston • Philadelphia
Pittsburgh • Chicago • Tulsa • Portland • Indianapolis
San Francisco • Houston • Denver • Seattle • Los
Angeles • Cleveland • Charleston, S. C. • Toronto

send today!

Please send me a copy of your catalog on Saran Lined Pipe, Valves and Fittings.

NAME _____

TITLE _____

COMPANY _____

ADDRESS _____

CITY _____

STATE _____

SP-67

SARAN LINED PIPE

DOW

product

93-13-06, 1949, No. 6, 1; *Prev. Det. Abs.*, 7, Plas 90 (1949).

• Results of weathering and accelerated weathering tests on commercial transparent plastics are given. Tests for degree of change in brittleness, scratching by wind-borne particles and of hazing were carried out.—RPI.

• Duplex Materials

6.7

Oxidation of Cemented Carbides. R. Kieffer and K. Kolbl. *Powder Met. Bull.*, 5, No. 3, 38-39 (1950) May.

The oxidation mechanism of cemented carbides was studied in respect to the infiltration techniques in the development of oxidation-resistant cemented

carbides. Photographs show this mechanism.—INCO.

6.7, 8.10, 3.6

Corrosion Problems in Powder Metallurgy. (In German.) H. Grubitsch. *Werkstoffe u. Korrosion*, 1, 89-93 (1950) Mar.

Shows that the corrosive properties of sintered bodies or powders differ from those of cast metals. Sintered articles are primarily corroded by galvanic action induced by cold-working or by various external factors. Methods of reducing the rate of corrosion are discussed. 35 ref.—BLR.

6.7, 3.5

Metal Ceramics. *Mach. Des.*, 1950 101-102, Oct.

This is a brief review of the latest data on the newly developed combina-

tion metal and ceramics material for high-temperature duty. Comparative properties of typical high-temperature materials and Metamic metal ceramics are discussed and information on present manufacturing possibilities is presented.—TDD.

6.7, 3.5

Metals and Refractories Combined in High-Temperature Structural Parts. J. B. Campbell, *Mat. & Meth.*, 31, No. 5, 59-63 (1950).—MI.

EQUIPMENT

• Engines, Bearings and Turbines

7.1, 2.4

Ultrasonic Testing of Gas Turbine Disks. *Met. Prog.*, 1950, April 468-473.

Jet-engine turbine disks made of "Timken alloy" (nominally 16-25-6 chromium-nickel-molybdenum) have been inspected by ultrasonic methods for some years. In a recent survey, a Sperry Type-SRO4B Reflectoscope was used to examine 839 partially upset forgings made from 19 different heats. A complete search was made over one of the two parallel as-forged faces, using a flat, 1-inch search crystal with a testing frequency of 2¼ megacycles, as well as a ¼-inch crystal at the same frequency. Better penetration of the sonic beam was obtained with the larger crystal, as evidenced by less loss of back reflection. An analysis of inspection reports shows that minor indications found in intermediate stage of forgings are not necessarily a cause for rejection. It is concluded that the ultrasonic inspection procedure is entirely practical from a production standpoint.—TDD.

7.1, 3.5

Stress Corrosion in Turbine Blades of 5% Nickel Steel. A. Rau. *Mitt. Ver. Grosskesselbesitzer*, 1949, 25-31. *Werkstoffe u. Korrosion*, 1, 279 (1950) June-July.

Investigation of failed steam turbine blades. Data on structure and mechanical properties are given. Cracking was due to stress corrosion. Steel contained 0.17 carbon, 0.3 silicon, 0.33 manganese, 0.007 phosphorous, 0.26 chromium, 4.9 percent nickel.—INCO.

7.1

Metals for Gas Turbines. N. L. Mochel, Westinghouse Elec. Corp. *Mech. Eng.*, 1950, June, 462-466.

Progress made in metallurgical research for the development of gas turbines proposed for application in ships and locomotives, for oil and gas pumping service and for stationary primary power is discussed. Metals for combustion liners, turbine casings and ducts, high-powered bolting, turbine rotors and blading or buckets are discussed, together with various methods for manufacturing turbine blades and rotors. Various alloys have been fairly well explored for temperature ranges of 1200-1500 degrees F, and research is being conducted to develop alloys that might have worthwhile load-carrying ability at higher temperatures, such as 1600-1750 degrees F. Chromium-base, titanium, molybdenum and molybdenum-base alloys and alloys containing increasing amounts of tungsten are among the materials considered.—TDD.

A BURIED TREASURE

FOR

CORROSION CONTROL...

WITH

Standard Magnesium Anodes



If you have a corrosion problem, Standard Magnesium Anodes can truly be a "Buried Treasure" of savings for you.

HERE'S HOW...

A good anode is like a good car battery... it gives you efficient, long-lasting service at a minimum cost. That is what Standard Magnesium anodes offer.

Certified Spectrographic Analysis records are furnished with all anodes shipped, insuring the user that he is receiving a product that will deliver maximum current efficiency.

Write for our free booklet on corrosion control and let our engineering consultants explain how we can serve you.



Standard Magnesium Corporation
TULSA, OKLAHOMA

INDEX TO ADVERTISERS

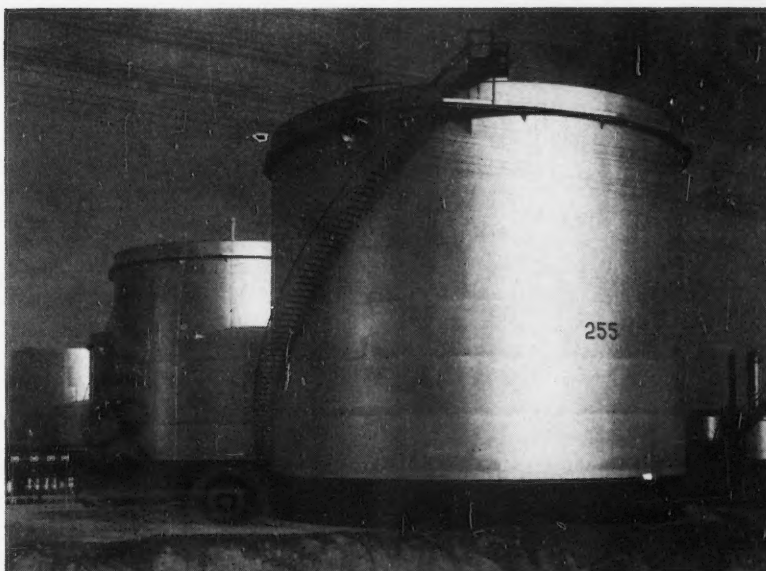
Vol. 7 December, 1951 No. 12

Acme-Fisher Division,	6
Broadway Rubber Corp.	33
American Brass Company	
American Smelting & Ref. Co.,	xiii
Federated Metals Division	30
Apex Smelting Company	
Bakelite Company,	35
Union Carbide & Carbon Corp.	
Barrett Division,	x
Allied Chemical & Dye Corp.	9
Bart Manufacturing Co.	
Bauer & Black,	5
Div. of Kendall Co.	456
Bechtel Corp. & H. C. Price	23
Brance-Kruchy Co.	39
Calgon, Inc.	42
Cathodic Servicing Co.	10
Centriline Corp.	45
Chicago Bridge & Iron Co.	16
Classified	29
Corrosion Directory	30
Corrosion Engineering Co.	Inside Front Cover
Dearborn Chemical Co.	14
Dixie Tank & Bridge Co.	ii
Dowell, Inc.	xiv
Dresser Manufacturing Div.	Inside Back Cover
Duriron Co., Inc.	21
Earl Paint Corp.	22
Electro Rust-Proofing Corp.	14
Elsevier Press, Inc.	6
Gardner Laboratory	xi
Good-All Electric Mfg. Co.	16
Haering, D. W. & Co.	ix
Harco Corporation	24
Harper, H. M., Co.	24
Heil Process Equipment Co.	
Hill, Hubbell & Company,	46
Div. of General Paint Co.	i
Hills-McCanna Company	19
International Nickel Co., Inc.	17
Insulmastic Corp.	15
Koppers Co., Inc.	37
Johns-Manville Co.	31
James E. Mavor Co.	13
Mayes Bros.	8
Metalweld, Inc.	20
Michigan Pipe Company	viii
Minnesota Mining & Mfg. Co.	vii
Monsanto Chemical Co.	
National Carbon Company,	41
Union Carbide & Carbon Corp.	32
Nelson Electric Mfg. Co.	11
New Jersey Zinc Co.	20
Nicolet Industries, Inc.	12
PESCO	7
Pittsburgh Coke & Chem. Co.	27
Prufcoat Laboratories, Inc.	36
Royston Laboratories, Inc.	vi
Rust-Oleum Corp.	
Saran Lined Pipe Co.	43
Dow Chemical Co.	8
Service Engineers, Inc.	44
Standard Magnesium Corp.	Back Cover
D. E. Stearns Co.	38
Tapecoat Co., The	xv
U. S. Stoneware Co.	4
Williamson, T. D., Inc.	

7.1

Engine Wear. Harold Myers. *SAE Journal*, 58, 46-49 (1950) Aug.

Summarizes proceedings of 1950 SAE Summer Meeting round-table discussion. Relative merits of materials in terms of test and service-backed data were argued, including chromium plate for bearings and piston rings, cast iron vs. steel crankshafts and camshafts, tungsten carbide tappet faces and nickel-resist piston inserts. Ring and piston failures were described.—BLR.



HORTON FLOATING ROOFS

... reduce corrosion in storage tanks

You can effectively reduce corrosion on the inside of oil storage tanks by equipping them with Horton Double-Deck, Pontoon or Pan Floating Roofs. All three types of Horton roofs float directly on the liquid in the tank. The elimination of the vapor space practically eliminates corrosion on the underside of the roof and the inside of the tank shell above the liquid. The corrosion of the tank bottom is also materially reduced because relatively little rust drops from the roof and shell.

The Horton Double-Deck Floating Roof is the most recent design of all three roofs. It has a double deck with an insulating air space over the entire area of the tank. The bottom deck is in contact with the liquid at all times.

The Horton Pontoon Floating Roof covers half the area of the tank with its pontoon section. Vapor caused by boiling when temperatures are high collect under the center of the roof and provide insulation against further boiling. The entire bottom of the roof is normally in contact with the liquid.

The Horton Pan Floating Roof provides maximum economy for tanks storing liquids of low volatility. The bottom of the deck is in contact with the liquid at all times and there is no vapor space between the roof and the liquid.

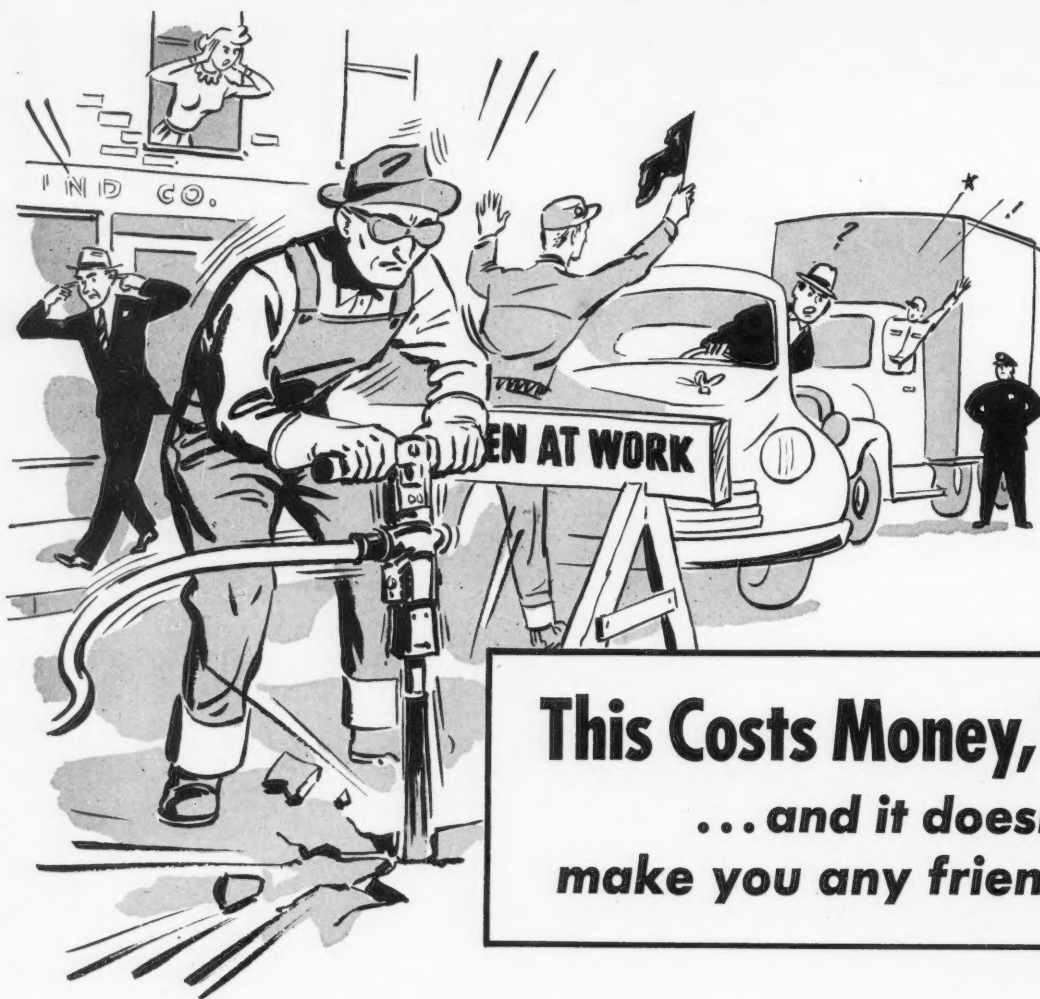
Write our nearest office for more details on efficient Horton Double-Deck, Pontoon or Pan Floating Roofs.

CHICAGO BRIDGE & IRON COMPANY

Atlanta 3 2137 Healey Building
Birmingham 1 1552 North 50th Street
Boston 10 1060—201 Devonshire Street
Chicago 4 2119 McCormick Building
Cleveland 15 2248 Guildhall Building
Detroit 26 1561 Lafayette Building
Havana 402 Abreu Building
Houston 2 2159 National Standard Building

Los Angeles 17 1552 General Petroleum Building
New York 6 3328—165 Broadway Building
Philadelphia 3 1661—1700 Walnut Street Building
Salt Lake City 4 563 West 17th South Street
San Francisco 4 1572—200 Bush Street
Seattle 1 1363 Henry Building
Tulsa 3 1640 Hunt Building
Washington 6, D. C. 1166 Caffritz Building

Plants in: BIRMINGHAM, CHICAGO, SALT LAKE CITY, and GREENVILLE, PA.



This Costs Money, Too
*...and it doesn't
 make you any friends!*

Pipe for utility distribution systems deserves even better protection than pipe for pipelines. For one thing, it costs more to dig up when something goes wrong. Also those noisy pavement-breakers and traffic-snarling holes in the streets don't do your public relations any good.

Sure, factory coated pipe costs a shade more, but it pays off by staying in the ground longer and saving on maintenance expense.

P.S. To our pipe coating plants at Girard and Lorain, Ohio, we have added a third at Hammond, Indiana—centered in the steel pipe mill section of the Chicago Switching District. This location enables our customers in the west and southwest to take advantage of the Hill, Hubbell process with faster deliveries. Minimum freight rates include the privilege of coating and wrapping pipe in transit. The new plant has ample storage space.

Hill, Hubbell and Company
 Division of GENERAL PAINT CORPORATION

Headquarters: 3091 Mayfield Road, Cleveland 18, Ohio

**Leaders in
 Pipe Protection
 for a
 Quarter Century**

Engineers report:



"No Durco Type F Valve has ever stuck!"

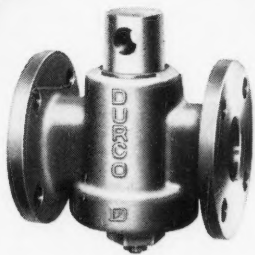
A year and a half of careful checking of several thousand Type F valves in actual installations has not revealed a single case of sticking. Even in the toughest chemical service, the Teflon sleeve prevents freezing and insures ready operation.

Let us send you all facts about this sturdy, simple corrosion resisting valve.

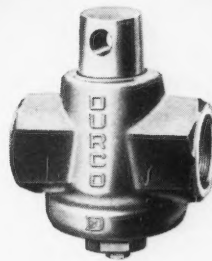


A product of
The Duriron Company, Inc.
Dayton, Ohio

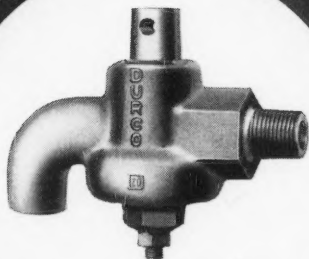
Manufacturers of corrosion resisting equipment exclusively since 1912.



Sizes: 1/4" to 2"
Flanged ends



Sizes: 1/4" to 2"
Screwed ends



Sampling valve
male or female
connection



Write for Bulletin 647



Christmas Cheer

*With the keenest appreciation of your goodwill
and patronage . . . with a sincerely repeated pledge
to serve you well with the finest Holiday Detector
equipment during the year to come . . . we send you
our cordial holiday greetings.*



The **D. E. STEARNS** *Company*

SHREVEPORT, LOUISIANA, U. S. A.

BETTER COATINGS CONSERVE STEEL

EEL